

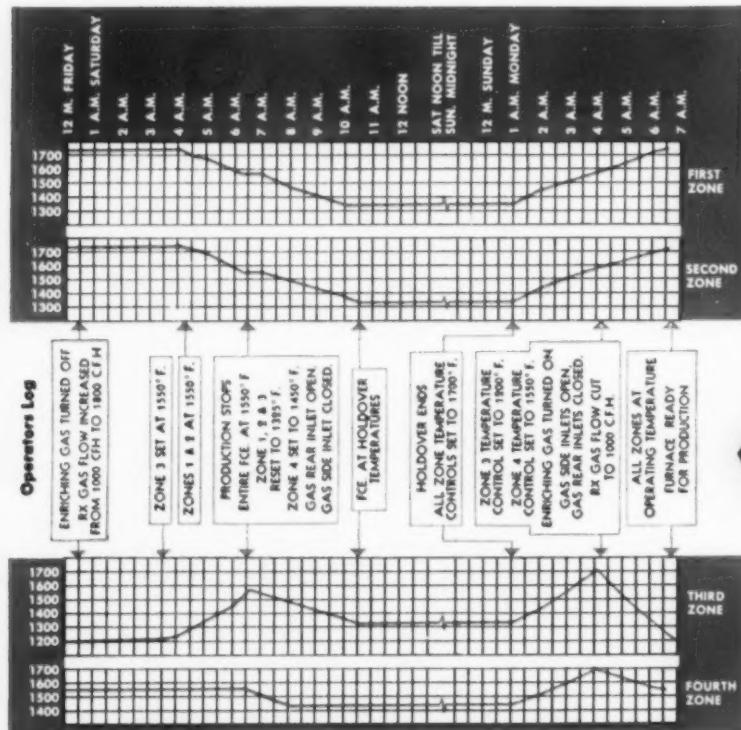
# metal *progress*

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# METAL PROGRESS

ERNEST E. THUM, Editor

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*A paper read before the Western Metal Congress and Exposition late in March wherein the author — himself a pioneering Ameri-*

*can researcher into the physical chemistry of steelmaking — reviews the trends in steel production and indicates ways*

*whereby output may be increased through improvements in mechanisms and quality and form of the raw materials.*

## STEEL-MELTING PRACTICE

By CHARLES H. HERTY, Jr.

Past President, American Society for Metals

Assistant to Vice-President, Bethlehem Steel Co., Bethlehem, Pa.

A DISCUSSION of "steel-melting practice" usually centers around particular phases or details of the making of a heat or heats of steel. There have been innumerable papers dealing with slag-metal reactions, deoxidation, pouring practice and other phases of steelmaking practice, but the purpose of this paper is to present a somewhat broader picture of the subject, dealing more with the general subject as affected by the industry's growth in the past quarter of a century.

The ingot capacity of the country has steadily increased over this period, with a period of acceleration during the recent war. The actual capacities in net tons given in the American Iron & Steel Institute's annual statistical reports for selected years are shown in Table I.

Table I — Steel Ingot Capacity of the United States

YEAR	OPENHEARTH	ELECTRIC	BESSEMER	TOTAL
1920				62,313,591
1925				68,473,222
1930	61,884,892	1,458,582	9,608,407	72,985,406
1935	68,544,310	1,053,370	8,842,400	78,451,930
1940	73,721,592	1,882,630	6,009,920	81,619,496
1946	81,236,250	5,500,290	5,154,000	91,890,560

The peak peacetime and wartime production years during this period were, for 1929, 63,205,490 net tons, for 1944, 89,641,600 net tons, and for 1946, an estimated 66,590,604.

The growth of almost 30,000,000 tons in capacity was divided between two processes, and the

general growth trend in the different processes is shown in Table II by the percentage of total production which each one contributed.

Table II — Percentage of Total Production

YEAR	OPENHEARTH		ELECTRIC	BESSEMER
	BASIC	ACID		
1920		77.7	1.2	21.1
1925	81.7	2.1	1.4	14.8
1930	84.2	1.9	1.5	12.4
1935	89.2	1.0	1.6	8.3
1940	91.0	1.0	2.5	5.5
1945	89.2	1.1	4.3	5.4

The above table shows the increasing use of the basic openhearth process at the expense of the bessemer, the preponderance of basic openhearth steel being made, and the significant increase in electric furnace tonnage.

If we direct our examination toward the fields of alloys, we note the proportion of alloy steel ingots produced and its manufacture by process in Table III, on the next page.

From Table III we see that the tonnage of alloy steel has increased, but note that the alloy steel production as a percentage of the total has been fairly constant (except for the war period) for 17 years. The country's demands for carbon steel have increased at about the same rate as the demand for alloy steel. Another interesting point is the high percentage of alloy steel produced by the openhearth process.

**Table III—Production of Alloy Steels**  
(Net Tons of Ingots)

YEAR	NET TONS INGOTS	PER CENT OF TOTAL STEEL	PER CENT PRODUCED BY	
			OPENHEARTH	ELECTRIC
1929	4,432,072	7.0*	84.6	12.9
1935	2,374,017	6.2	80.5	19.5
1940	4,965,887	7.4	74.1	25.9
1943	13,149,818	14.8	70.1	29.9
1945	8,647,711	10.8	67.6	32.4
1946	6,056,438†	9.1†	—	—

\*2.5% reported as bessemer and crucible steel.

†Estimated.

### *Size of Units*

The wartime increase in U.S. steelmaking capacity was largely accomplished, as indicated in Tables I and II, by increase in basic openhearth steelmaking facilities. Although statistics are not readily available, year by year, on the number and size of furnaces, it can be stated with considerable confidence that the average openhearth furnace of 1920 tapped about 100 tons of metal every 12 hr.—an output of about 200 tons per day. The size of new furnaces has been gradually increasing until at the present time a new shop will generally consist of 200-ton furnaces, which should tap at least 400 tons per day. A furnace of this type recently produced over 17,000 tons in a month, an average of 2.7 heats per day.

The iron units necessary for this increased capacity obviously had to come from either scrap or pig iron (or to some extent from ore in connection with high-iron charges). Now it is generally understood that, with an expanding production, the supply of scrap cannot keep up with the demand, and it has therefore been necessary for the industry to increase blast furnace capacity concurrently. This was accomplished in much the same way as in the openhearth, that is, by increasing the size of new units and dropping out uneconomical small units. The following table shows the changes in blast furnace capacity per year and per furnace.

**Table IV—Blast Furnaces**

YEAR	NUMBER OF FURNACES	TOTAL CAPACITY IN TONS	CAPACITY PER FURNACE	
			PER YEAR	PER DAY
1920	452	57,950,088	128,208	391
1925	395	57,288,437	145,034	442
1930	300	58,979,060	196,597	599
1935	258	55,854,280	216,489	660
1940	231	57,609,590	249,392	760
1945	241	67,340,590	279,419	861

The most modern blast furnaces are generally rated at 1200 to 1300 tons per day, and a furnace with specially prepared materials produced 1591 tons per day over an extended test period. With such large tonnages and with prospects of still larger outputs through advances in technology of raw material preparation, the bottleneck in blast furnace production may well be the ability to get the materials into the furnace. This opens the way for revised methods of charging blast furnaces of the future.

Electric furnaces have likewise gradually increased in size and capacity with the years and where the 15 and 25-ton furnaces were standard in 1920, modern furnaces are generally built to tap from 50 to 75 tons.

The increased productivity per unit has not, however, been a simple matter of increased size with attendant modifications in design. Many technical advances have been made which have increased the output and efficiencies of the various units and these have concerned themselves mainly with better utilization of heat and power, and proper preparation of the raw materials for the charge entering the furnace.

**Fuel**—In 1920 the major fuel used in openhearth furnaces was producer gas. In certain districts, natural gas was readily available, and oil was being used to a minor extent. With increased amounts of byproduct coke, coke oven gas was more widely used. However, the major trend has been toward the use of fuel oil, and this is the standard fuel of present-day steelmaking. Oil is supplemented by tar, pitch and byproduct gases (both coke oven and blast furnace) in many plants. The use of oil was an important step forward in improving the steel-melting rate for any given furnace; it also put into the operator's hands a tool whereby the control of temperature in the bath became much more positive—a very important item in connection with the expanding production of alloy steels in openhearth furnaces.

In electric furnace melting, improved automatic electrode control has been of great importance in speeding up melting with maximum heat absorption by the charge. A great deal more is known today about slag formation and control and more rapid methods of analysis have done much to speed up the working of heats.

**Refractories**—In both processes the development of refractories has progressed steadily. The faster melting rates quickly resulted in greater damage to the furnace linings, and heightened the interest in basic refractories for openhearths and sillimanite for electric furnaces. Basic front-walls and ends are common in many openhearth shops today. Experiments are under way both here and abroad on the all-basic furnace. A relatively recent

finding that high  $\text{Al}_2\text{O}_3$  in silica brick markedly lowered their refractory qualities (especially for roofs) has been of great interest in connection with the most recent efforts to improve the output of openhearths through minimizing down-time for necessary repairs.

In this connection, the use of mechanical equipment during the rebuilding and repair of furnaces has effected great economies in time. During the 1943 drive for more tonnage from existing equipment, the minimization of down-time for repairs was a major factor in increasing ingot tonnage.

### **Raw Materials**

Preparation of materials for the charge has received a great amount of attention and will unquestionably receive more if full advantage is to be taken of all the advances made in the past quarter-century and those just ahead of us. The major raw materials used in the steel industry are iron ore, coal, steel scrap, fluxes and air. All these have been subject to various processes of beneficiation, modification or preparation as operators strive to reduce the unnecessary burdens which poor raw materials place on the melting units.

Blast furnace operators have long realized the waste in smelting ores too low in iron with coke too high in ash and sulphur. Fortunately, we were blessed with tremendous reserves of high grade iron ores; beneficiation (concentration) has so far been unnecessary on any large scale. However, the time has come when the quality of ores which we shall use in the not too distant future must be improved, and large sums of money are now being spent in research and development projects for the beneficiation of the huge reserves of lower grade iron ore remaining in this country.

The pioneering work of the U. S. Bureau of Mines investigators on the sizing of materials for the blast furnace charge centered attention on the desirability of avoiding mixtures of fine and coarse material in the same charge. "Size beneficiation" of ore is now a common practice. Too-coarse ores are crushed, many ores are washed, and much fine ore is screened and sintered. Concentrates from other mining operations are sintered, generally with some flue dust, in order to give a more suitable burden for the blast furnace, with resultant increases in production and decrease in fuel consumption per ton of iron produced.

**Coal** — With increased mechanization in coal mining, more rock gets into the coal and its ash content correspondingly increases. In many mines the coking coal is crushed and washed in order to eliminate this excess and some of the pyritic sul-

phur, thus making available a better coke for the blast furnaces. As yet no methods have been devised for eliminating organic sulphur in coal — this is a problem for the future. As the ash content of the coke increases, more limestone is required to flux it and this in turn requires more coke for the generation of the heat required for that operation. In addition, high-ash cokes are generally weak and do not properly support the column of raw materials in the furnace; thus the materials pack, and production decreases through the failure of the charge to move smoothly down the shaft of the furnace.

Incidentally, as an illustration of some of the many things we don't know, there is as yet no recognized test which will determine the quality of coke. In the present state of our ignorance we depend on the performance of the blast furnace to tell us whether the coke is good or bad.

### **Pig Iron and Scrap**

With the proper ore and coke available the blast furnace has little difficulty in supplying a satisfactory grade of pig iron for the steel-melting furnaces. In many instances, however, it has been found that a hot iron with a closely controlled, low-silicon content (say 0.50 to 0.75%) is highly desirable if maximum output is to be obtained from the openhearth. This is primarily due to the decreased amounts of fluxes required in the melting operation, and in the ease of controlling phosphorus and sulphur with iron charges low in silicon. This condition is arrived at either by good operation combined with the proper raw materials, or by partially bessemerizing the hot metal, or by adding roll scale to the metal before it is taken to the openhearth. While the latter two methods are not practiced extensively in this country, they are certainly steps in the right direction in the preparation of a raw material for the steel-melting charge.

As has been mentioned previously, the steel-making process depends for its iron units on pig iron and scrap (with some from the iron ore added as required to complete the oxidation of the impurities). The control of the iron has been discussed in the preceding paragraphs. Let us now say something about the scrap.

Steel scrap is defined as "home" or "revert" when its source is the operations which take place in the steel plant, or as "purchased" when the scrap originates outside of the steel producer's plant. As is well known, the scrap is charged into the furnaces by bringing up trains of buggies on which charging boxes full of scrap are placed. The boxes are dumped one at a time into the furnace and the length of time required to charge is primarily dependent on the amount and type of scrap and the

size of the charging box — which, incidentally, has changed but little over the years.

Much purchased scrap (and some home scrap) is too large in its original size to be placed in charging boxes, or too light to give a satisfactory weight per box. Many methods are therefore used in scrap preparation. Among these are shearing, breaking by a drop ball, torch cutting, bundling, baling, coiling. All these methods increase the amount of scrap which can be placed in a given size box and this facilitates charging and thus speeds up the melting process. More thought must be given to this problem of charging because it is often the bottleneck which holds back production from the entire shop. Large boxes, more powerful charging machines, better preparation facilities in the

scrap yard, and possibly redesign of charging doors on the furnaces are steps which will probably be taken in the future to speed up this phase of steel-making.

Many modern electric furnaces are charged by swinging the roof aside, lowering a single box or bucket into the furnace and bottom-dumping this. The entire operation is a matter of minutes instead of hours. Electric furnace operators have also given much thought to the proper sequence for arranging the various types of scrap in order to get the maximum melting rate.

Another phase of scrap preparation which is highly important today is the segregation of non-ferrous metals and segregation of alloy scrap. The former has been a problem of inspection for many

#### *Molten Steel From Furnace to Ladle*

Photo by Bethlehem Steel Co.



years, and—as a result of the experience gained during the war—the latter is common practice today. Alloy scrap segregation serves two purposes: First, it makes available alloys for introduction into proper grades of alloy steel; second, it assists in preventing the contamination of carbon steels with unwanted elements.

One of the important aids in the production of a large tonnage of alloy steels during the war was the result of two things in combination—the development of the low "double-alloy" and the "triple-alloy" steels, and the successful efforts of the industry to fully utilize the alloys coming back in the scrap through the proper segregation of alloy scrap. The lessons learned during that period have been well worth while in the postwar period—and, incidentally, have given to industry an additional group of steels which are easily produced in the openhearth furnace.

**"Direct" Iron**—It has been mentioned previously that with an expanding production of steel, the scrap supply is apt to be short, and required iron units must then be furnished from ore, either through the medium of the blast furnace or by some other method. Much thought and some effort have been given to the proposal that iron units may be obtained "directly" from ore. This, of course, is actually accomplished when ore is charged with pig iron in the openhearth, but the amounts of ore so reduced are generally limited by the pig iron charged. Another limiting factor can be the volume of ore put into the openhearth as well as the amount of gangue introduced with the ore. It is not generally recognized that with a charge of about 65% hot metal, the metal obtained from the ore charged may amount to 10% of the total—quite a "direct reduction process" in itself. An extra 3% of metal has been obtained from ore in recent experiments on 135-ton furnaces by charging extra ore and coke in addition to the regular charge of hot metal, ore and scrap.

For tonnage recovery of iron "direct" from ore, it must be remembered that the reduced material must be quite low in impurities so that no undue burden is placed on the refining furnace, and that the product must be dense enough to charge easily and efficiently. It does not necessarily have to be completely reduced, as the carbon and silicon in pig iron are very efficient deoxidizers. In any event, as long as scrap is short, there is always the possibility of using a material which has been prepared from iron ore without going through the blast furnace, and utilizing it in conventional steelmaking processes.

**Openhearth ores** are used for the elimination of carbon after the heat is melted ("feed ore"), and for oxidation of impurities where the pig iron

charged is too great in amount to allow the normal oxidation of the scrap during melting to accomplish the desired result ("charge ore"). Charge ores should have these general characteristics: (a) They must not be too fine, (b) they must not contain too much  $\text{SiO}_2$ , and (c) they must not contain too much combined water, else they will tend to "blow" when contact is made with hot metal. Nodulizing and sintering of fine ores of desirable chemical analysis, thus eliminating objections from (a) and (c), have made available large quantities of available material which otherwise could not be successfully used in the openhearth.

### Air

Finally, we arrive at our last raw material—air. There are actually more tons of air used per ton of ingots than any other raw material! Furthermore, the supply is inexhaustible. At the present time we are really beginning to do something about preparing the air for use.

Many years ago it was held that the moisture in the air was detrimental to the best interests of the blast furnace, and in the past ten years some furnaces have been equipped with air conditioning equipment which can control the moisture at certain desired levels. These operations have given widely diversified results, indicating perhaps that it is not so much the content of moisture, *per se*, but a combination of circumstances which give favorable results in some localities, and negative in others.

More recently experiments have been planned to use oxygen-enriched air on a full-size blast furnace and to determine its effect on operations. This will be watched with the utmost interest as no one yet has been able to predict exactly what a furnace will do with a new diet. While this experiment is in process of preparation, a regular rash of experiments has broken out on the use of oxygen in the openhearth, both as an aid to combustion and as a means of oxidizing the bath to speed up the elimination of carbon. There seems to be little doubt that this method of attack will produce rewards, the extent of which may be predictable in the not too distant future.

In conclusion, it would appear that steelmaking in the future will be on an increasing scale, that the steel and iron-making units will become larger, or be provided with materials which will enable them to increase considerably their production per unit. The technical advances necessary to do this job will be of paramount importance, and we should look to the future with confidence in the constructive effort of metallurgists, engineers and steel plant operators.

1945 RECIPIENT  
THE A. S. M. MEDAL FOR THE ADVANCEMENT OF RESEARCH



Gerard Swope

PRESIDENT EMERITUS, GENERAL ELECTRIC CO.

## GERARD SWOPE

IN 1943 the American Society for Metals, by action of its Board of Trustees, established "The  Medal for the Advancement of Research". The conditions were that it was to be awarded to "an executive in an industrial organization, the principal activity of which is the production or the fabrication of metals. He shall be one who, over a period of years, has consistently sponsored metallurgical research or development and by his foresight and his influence in making available financial support has helped substantially to advance the arts and sciences relating to metals."

In 1943 this medal was awarded to Roy A. HUNT of Aluminum Co. of America, in 1944 to ROBERT C. STANLEY of International Nickel Co., in 1945 to GERARD SWOPE of General Electric Co., and in 1946 to RUFUS E. ZIMMERMAN of United States Steel Corp.

What kind of men are these who receive this dignified and unequivocal plaudit?

As to GERARD SWOPE, the bare facts may be quoted from the official citation: "In recognition of his pre-eminent share in many of the important developments in metallurgy in recent years. During his presidency of General Electric he demonstrated his faith in the future by his unfailing support of a program of fundamental and applied research in which metallurgy has played a predominant role. Scientists and engineers under his direction made important additions to the knowledge of metallurgy, and in the war emergency their contributions have been outstanding. His sustained interest in metallurgical research and his influence in providing financial support for its continuance have produced a profound effect upon the metallurgical science of his time."

This is the skeleton. What flesh clothes it?

Beginning as an electrical engineer, he became a great salesman, then a business statesman; always deeply patriotic, his country had first call on his energies, yet paralleling this public life, well known to the industrial public, is his career as a benevolunteer — long-standing and continuing philanthropy.

GERARD SWOPE's business career is technically over because General Electric, of which he was

president from 1922 to 1939, has an age limit for its executives, and in 1939 he was 67 years old. He then became president emeritus and would have remained continuously so had not the recent war summoned him like another Cincinnatus back from retirement to function again as G.E.'s president, while his successor CHARLES E. WILSON was on the War Production Board in service comparable to SWOPE's federal office during World War I.

His re-election to the presidency of G.E. leaves the archivists of that industrial empire in the same puzzle as those who quibble as to whether GROVER CLEVELAND was both the 22nd and the 24th President, and FRANKLIN DELANO ROOSEVELT the 31st or the 32nd! General Electric's ordination is not so concatenated. There have been but three G.E. presidents: CHARLES A. COFFIN, GERARD SWOPE and CHARLES E. WILSON.

GERARD SWOPE is a great salesman who became a great business statesman, and as such a great appreciator of scientists and engineers (including metallurgists) in industry. The fact that he was one of the first graduate electrical engineers in this country — from Massachusetts Institute of Technology, in 1895 — doubtless helped him to that appreciation.

The fact that he had academic engineering certainly helped him in his business career. From M.I.T. he — a bright, alert, energetic, cooperative young man of 23 — got a job with Western Electric in his home town of St. Louis. Here the civitarians, notably the (Anheuser) BUSCHES and the PULITZERS, were already looking forward to the St. Louis Exposition of 1904. That world's fair established the young electrical industry as a purveyor of light, power and domestic conveniences. But that is looking forward nearly ten years; the first electrical distribution system had been in operation only since 1882.

Western Electric Co. at that time was not limited to the building of telephonic equipment, as now, so young salesman SWOPE, around the turn of the century, proceeded to attract so much business that its directors became optimistic and he had to go abroad to make new markets for an excess potential of manufacturing facilities. He discovered such great and far-flung foreign markets that

when International General Electric became a logical and commercial necessity he also became its logical and necessary president.

Later, by commercial evolution, he became president of General Electric, and board chairman of International General Electric, which G.E. owns locks, stocks and bookkeeping machines.

We have said that GERARD SWOPE was a business statesman. Three facts, among many pertinent ones, attest:

He kept an army of G.E. employees contented and free from strikes through all the years until the labor revolution of 1946.

He kept, also until last year, General Electric from being law-suited on charges of violating anti-trust laws.

He fostered research. In his reply to his citation he said: "I am especially pleased that this is a medal for the support of research. We in the United States in the past 40 or 50 years have found the magic formula for abundance. The formula seems simple now. It is to perform and make use of research along a wide front to discover new truths, leading to new and improved products, new and improved methods, better facilities for production, and more and better jobs."

Industrial scientists and engineers owe him particular gratitude for this fostering of research. G.E.'s research laboratory was one of the first industrial ones in the U.S. and remains one of the greatest in the world. Under his presidency the G.E. research program supported Dr. WILLIAM D. COOLIDGE, developer of tungsten lamp filament and of cascading X-ray tubes. It fostered fundamental work on molecular behavior of gases at surfaces for which one of his research workers, Dr. IRVING LANGMUIR, won the 1932 Nobel prize in chemistry, and which later turned out to be of prime importance to the construction of all sorts of incandescent lamps, electronic tubes and vacuum equipment. He encouraged scientists who now are G.E. vice-presidents: Dr. HARRY ALONZO WINNE, in charge of G.E. engineering policy; Dr. CHAUNCEY GUY SUITS, in charge of the expanding research laboratories; Dr. ZAY JEFFRIES (past-president of American Society for Metals), in charge of the expanding chemical department. These three form a special company committee to supervise the atomic energy facilities at Hanford, Wash., which G.E. is operating for the U.S. Atomic Energy Commission.

Briefly, this was his business career.

Deepest of his interests is his family, about whom he has succeeded in letting almost nothing be known to the general public—even to most of his business associates. He has a charming "farm"

of woods, rocks, a lake and bridle paths near Ossining in Westchester County, N. Y. The formal name of the estate is "The Croft". Here he rides, swims, relaxes, enjoys his energetic family. Here Mrs. SWOPE, a Bryn Mawr graduate, is the unbossy, dearly beloved boss. From here their only daughter, HENRIETTA, went to Barnard and Radcliffe, became a Harvard authority on variable stars in the Milky Way, helped develop "loran" for wartime navigation. ISAAC, the eldest son, whom the family call "Ike", went to Harvard and M.I.T. and became an authority on nuclear physics. Son GERARD (Dartmouth and Harvard Law) was a commander in the Navy, now practices law in New York, being general counsel for International General Electric. Son DAVID, formerly a captain in the Air Force, is building houses in Westchester County. Youngest son JOHN, not long out of the Navy, has been in California deciding just what financially different university and career to enter.

With his children now pretty much on their own and a grandchild (Ike's daughter) already at Bryn Mawr, GERARD SWOPE at 75 has more time and attention than ever for good deeds in behalf of his fellow men.

He has always been philanthropic. His willingness to help the other fellow was a major factor in making him a superb salesman.

But to be rated a lover of his fellow men one must act through conventional and established channels. Mr. SWOPE's first outlet was as playground commissioner of his native St. Louis—that was far back in 1901. He soon got an opportunity to be chairman of that smoke-beset community's bath commission. The help he later gave the employees of General Electric was less conventional: There is now a \$400,000 Gerard Swope Foundation to help them and their children acquire advanced scientific and technical educations.

For the community at large he has worked for low cost housing, good roads, state parks, and numberless charity collections. He helped draft the Social Security Law and is campaigning for passage of a bill for health insurance for all inhabitants of the United States. Says he: "You just can't provide health insurance for 135,000,000 people on a voluntary basis!"

What he is also currently trying to do is the quintessence of benevolence. He is fostering a national retirement plan for the employees of health and welfare agencies, and is trying to persuade those penny-pinching professional expenders of other peoples' generosity to pay 5% of the salary lists toward pensions which will take care of them in their old age until the social security act blankets them all.

MYRON WEISS

# A. I. M. E.'s DIAMOND JUBILEE

By EDWARD C. McDOWELL, JR.

OUR ILLUSTRIOUS sister society, The American Institute of Mining and Metallurgical Engineers (hereinafter called A.I.M.E. for short), celebrated the 75th anniversary of its founding with a full week of interesting social and technical activities at the Waldorf-Astoria in New York during mid-March. The high point of the anniversary was a World Conference on Mineral Resources which took up the first three days. At this carefully planned symposium authoritative speakers from this country and abroad discussed topics in four main categories — (a) world mineral resources, (b) world mineral economics, (c) the mineral industry and atomic energy, and, finally, a forecast of mineral technology. During the last three days of the week the several divisions of the Institute held their regular annual meetings at which more than 200 technical papers and reports were presented.

Altogether, the 75th anniversary was a gratifying success. The planning and arrangements were excellent, the addresses were interesting and of timely importance, and the 3000 members and guests had every reason to congratulate themselves on a worthwhile and well-spent week.

\* \* \* \* \*

The Waldorf-Astoria, like New York City itself, is immense, and easily swallowed the A.I.M.E. activities, so that it is unlikely that many of the other guests of the hotel or even the denizens of its numerous lobbies were aware they were sharing the premises with a 3000-man world conference. But for A.I.M.E. members, honorary members, senior members, associates, junior members, Rocky Mountain members, junior foreign affiliates, honored guests, distinguished speakers, and an unusual turnout of wives and sweethearts it was certainly an important and pleasurable occasion. A glimpse at the opening day will give the flavor of the entire program:

President Louis Cates welcomed the members at a luncheon and there was another welcome from Governor Dewey. At 5:30 members and

guests overflowed several acres of reception rooms at a mass cocktail party during which photographers used up dozens of flash bulbs and a conscientious Belgian gentleman from the United Nations headquarters tried unsuccessfully to find someone who could give him information and statistics on industrial activities. Since few if any of the guests had brought along their brief cases it is doubtful whether he learned very much. After a decent interval most of the gentlemen—and all of the ladies—repaired to the grand ballroom to witness an elaborate fashion show put on especially for their benefit, with Jinx Falkenburg the featured attraction. As the models came and went, A.I.M.E. wives and sweethearts gave them solemn and beady-eyed scrutiny and muttered comments to each other on gores, pleats, tucks, peplums, *décolletages*, and skirt lengths. Most of the mining and metallurgical engineers present lit cigars and became bemused, but a surprising number of the unattached ones watched and listened carefully, evidently with the intention of carrying home a report. Just what the foreign members thought of the fashions is a moot point; it's always hard to tell what foreigners are thinking. After dinner, the evening was devoted to a formal reception for the guests, a ball, a midnight supper, and other revels.

These opening-day events are enumerated in order to show that A.I.M.E. observed the amenities on a scale appropriate to its dignity, and in general properly preheated its membership before subjecting them to the more solemn matters they had gathered to be informed upon. Certainly, great credit should go to Secretary Parsons, to his coworkers, and to the appropriate committees for their careful planning, good taste, and hard work.

\* \* \* \* \*

The speakers at the three-day World Conference on Mineral Resources were all distinguished men in their fields—business, science, politics, and banking—and their papers were for the most part general and nontechnical and covered a wide

range. Since the scope of A.I.M.E. includes mining, geology, metals, petroleum, coal, and minerals, it was natural that relatively few of the papers were devoted to metallurgy alone.

Thus, at the first day's session, Secretary of the Interior Krug spoke on our mineral resources; Charles White, president of Republic Steel, gave an excellent analysis of our iron ore resources and the future of our steel industry; Sir William Fraser, chairman of the Anglo-Iranian Oil Co. of London, discussed the future of the world petroleum industry; and Clinton Crane, head of St. Joseph Lead, gave his ideas on copper, lead, and zinc mining in the future. From this sample of the Conference fare it will be seen that most of the talks, as far as metallurgists are concerned, were of general interest, primarily.

Some of the papers were outstandingly good, and ranged in treatment from a scholarly discussion of the geology of coal by one of Scotland's leading coal figures, C. A. Carlow, to an adjectively-adorned polemic against Leftist tendencies by Virgil Jordan, president of the National Industrial Conference Board. Nuclear energy (or "nucleonics", as it's now fashionable to call it) naturally received a lot of attention, particularly in the paper by Harry Winne and Bruce Prentiss of General Electric which attempted to predict some of its future applications to industry. Their paper offered lots to think about, although their task is similar to what it would have been if one of Faraday's contemporaries had attempted to forecast the electrochemical industry at Niagara Falls. John Hancock, a former delegate to the United Nations Atomic Energy Commission, explained and defended the American plan for international control.

From a metallurgist's standpoint, probably the paper entitled "Metals and Alloys of the Future" by Zay Jeffries (who needs no introduction here) was of the most immediate interest. Dr. Jeffries saw the metallurgist repairing the now-shattered world and creating a brave new one with the tools and knowledge now at his disposal, but he warned that this could not happen "if we put our great industrial machine in a strait-jacket and dissipate much of our energy in fighting futile and illogical class wars". His address, which classified most of the commercially used metals and discussed their availability and usefulness in the future, is worthwhile reading for any metallurgist. Incidentally, Dr. Jeffries is a practiced hand at looking into the future and not too prone to overenthusiasm, for his Howe Memorial Lecture in 1930 was on "The Future of the American Iron and Steel Industry" and his Institute of Metals lecture in 1924 dealt with "The

Trend in the Science of Metals", and they did not lead any of his hearers very far astray. Another speaker with a crystal ball was A.I.M.E.'s retiring president, Louis S. Cates, president of Phelps Dodge, who gave an excellent paper (in collaboration with Howland Bancroft) on the "Techniques of Mineral Exploitation of the Future".

Obviously, *Metal Progress* is not the appropriate place to review or discuss all of these many fine papers; the foregoing sampling gives a general idea of their scope. For the rest, the 75th anniversary meeting witnessed the awarding of the Institute's several medals and other honors, and the installation of its president for the coming year, Clyde Williams, director of the Battelle Memorial Institute.

\* \* \* \* \*

The A.I.M.E. has become, with advancing years, quite a large organization (14,000 members in 73 countries), but with all its growth and its ramifications it has never strayed from the simple fundamental purposes laid down by its founders. It is doubtful that it would have survived or prospered if it had. The Institute was founded largely through the efforts of three mining engineers—E. P. Coxe, R. P. Rothwell, and Martin Coryell. The first two of these men had had part of their engineering education in Europe and had brought back with them a desire to organize American mining practices in the same pattern used by the scientific societies of Europe. It was at the invitation of these three men that 22 coal-and-iron men met at Wilkes-Barre in the heart of the then coal-and-iron industry to work out the aims and procedures of a proposed organization. While these 22 were for the most part Pennsylvania iron masters and mine superintendents, their aim was far from provincial: "The more economical production of minerals and metals, and the greater safety of those engaged in those industries." The first meeting then proposed to achieve these aims by "the exchange of experience and information" through "free intercourse". These principles—which are as old as science itself—still govern the A.I.M.E., as indeed they govern the functioning of all worthwhile scientific groups. (The safety problem, having more recently been taken up by governmental agencies, is not today as important to the Institute as it was at first.)

The A.I.M.E. today would astound but please its founders. From its original chore of serving coal operators and iron masters, it has grown into a vast clearing house of information in many separate but related fields of industry. But, as with all organizations of its kind, it is much more than a mere clearing house. It encourages progress and rewards it; it concerns itself with the

technical education of the next generation; it is a place for testing the merit of new ideas, and a place where merit can quickly receive wide recognition; it is a vast lens, big enough to bring the relationship of many diverse developments and industries into focus. Curiously, too, it is a common ground where firms and industries that are sometimes fiercely competitive foregather to strengthen each other's hand by the exchange of experience and methods—a seeming "equal and opposite reaction" to competition.

\* \* \* \* \*

Metallurgy as we know it today hardly existed in 1870, except for the rudimentary arts. At the A.I.M.E.'s first two meetings, none of the papers concerned themselves with metallurgy; in the first seven meetings only about a third of the 50 papers were metallurgical—and by today's standards few of these would be so classed. From that early period until the first world war—50 years—the A.I.M.E. was practically the only professional group concerned with metallurgical development and must receive a large share of the credit for encouraging the interchange of information on better and better methods of winning metals from their ores. During that half-century, in fact, the emphasis was on concentration, smelting, and refining. The art and science of physical metallurgy—the alloying and treatment of purified metals—did not surge to the front until it received the impetus of the first world war. Metallurgy began to be looked upon as a science, and an almost unknown one at that. At about that time, the A.I.M.E. was founded to fulfill the acute need for an association that could devote its entire energies to this complicated and fast developing science. Likewise the American Institute of Metals, which had had a somewhat meandering career as a brass foundry committee of the American Foundrymen's Assoc. and as an independent organization devoted to all cast and wrought nonferrous alloys, achieved financial stability and wider influence by associating itself with the A.I.M.E. in 1918 as the Institute of Metals Division. By 1928 the metallurgy of steel was also segregated in a new division called the Iron and Steel Division.

This trend toward separating its many interests into separate semi-autonomous groups, or "Professional Divisions", had led to the formation of its Petroleum Division in 1922, and resulted in the establishment of the Coal Division in 1929, the Mineral Industries Education Division in 1932, and the Industrial Minerals Division in 1938—all in addition to the two devoted to metals.

Of particular interest to metallurgists is the work of the Iron and Steel Division. Under its

guidance was founded a group of three specialized national conferences; the Openhearth Conference in 1925; the Blast Furnace and Raw Materials Conference in 1939; and the Electric Furnace Steel Conference in 1942. These annual conferences hold meetings, support research, publish their own proceedings, and operate almost like separate scientific societies within the Iron and Steel Division, which in turn bears the same relationship to the parent organization. So complex are these relationships that this reporter may be excused if he has not quite mastered them.

\* \* \* \* \*

The A.I.M.E., in fact, is—like the American Society for Testing Materials—an amazingly complex body with an elaborate interlocking structure of divisions, sections, committees, and subcommittees. With the spread of technology down the years the Institute has always been willing to expand and make room for more committees. Thus, since 1871, it has grown by the cell-division process until today it is a many-headed technological hydra. Its activities are governed, according to its latest directory, by approximately 70 standing committees organized under 29 main classifications; it has 32 local sections (or chapters) and two foreign sections; it supports 12 technical committees, of which the committee on mining methods alone is subdivided into about a dozen sub and sub-subcommittees; and is fenced off into the six professional divisions previously enumerated which, in turn, are subdivided into a total of about 95 committees. All this shows what you can do in 75 years!

Then there are 56 student chapters and affiliate student societies and, in conclusion, a Woman's Auxiliary which is big and busy enough to require 11 officers including five vice-presidents, and which might be thought to make coffee in the basement while the menfolks are in meeting, but which actually has a notable history of scholarship aids to engineering students and financial aid to libraries in small mining towns.

\* \* \* \* \*

A former secretary of the A.I.M.E., H. Foster Bain, writing in the *Mineral Congress Journal* for March 1928, speculated on the motives and forces that led to the founding of the Institute. He concluded, at some length, that it came into being "in response to a certain *Zeitgeist*"—a superb phrase that this reporter had to look up and will always cherish. The phrase could well be used as a motto on the Institute's seal, for the A.I.M.E.'s growth from a simple one-cell organism to its present intricate but useful structure has come about because its leaders have been alive to the spirit of the age and the needs of the times. ☺

*Electric strain gages have been widely and successfully used for studying stresses in members of complicated structures and in*

*machine parts during test loadings. When three such gages are clustered regularly about a point, it is possible to derive an accu-*

*rate estimate of the principal stresses existing there and their directions. A simplified graphical method is presented.*

## THE EQUILATERAL ELECTRIC STRAIN GAGE ROSETTE

By GIVEN BREWER

Consulting Engineer, Laguna Beach, Calif.

TWO ARTICLES were published by the present author in *Metal Progress* in July and August of 1945 describing the construction and functioning of the electric strain gage, the instruments necessary to record its indications and the method of translating these readings into figures representing stresses within the structure under observation. Cited in these articles were a few elementary applications of such gages when attached to structural units in axial directions. However, it was emphasized at the outset of the first article that the simplified concept of obtaining stress by multiplying a measured value of strain from only one gage by Young's modulus is only valid in cases similar to a simple tensile test piece, and then this concept is only true when the load and gage axes are parallel.

A little reflection will indicate that few parts of machines and structures are anywhere near as simple as the standard test piece. The location and direction of the principal stress in the web of a casting, or the wall of a vessel, is so difficult to predict that some experimental device is necessary to check the mathematical conclusions. Such a device, used to a great extent by testing engineers, is the "equilateral strain gage rosette", wherein three small electric strain gages are cemented to the area under study, close together, arranged so their axes correspond to the sides of an equilateral triangle. The orientation is immaterial as long as the direction of one leg is accurately determined in relation to any dimension of the part.

After such a rosette (or a group of them) is properly cemented to the surface to be studied and wired to proper instruments, the structure is loaded as desired and the resulting strains recorded for each of the gages. Confining attention to a single rosette, simultaneous readings along the three legs will give all the information necessary to determine the two principal stresses existing in the material at that spot and their directions. Although in very heavy-walled structures a stress in the third (thickness) direction may exist, this stress is usually small and of course equal to zero at the surface of the structure — that is, at the point of rosette attachment; hence this stress has no significance in this exposition.

Two-dimensional stress fields are completely defined by three quantities, namely the major principal stress ( $f_p$ ), the minor principal stress at right angles thereto ( $f_q$ ), and the angle  $\theta$  between one of the principal axes and a known reference axis. These are noted in the upper part of Fig. 1, where squares indicate elements of the structure on which a rosette is cemented.

Occasionally it is possible to determine the angle  $\theta$  by an inspection of the structure and the manner of loading, but in general the magnitude and directions of the principal stresses are unknown. To solve for the three unknown quantities, it is of course necessary to have three equations each containing all of the unknowns. It can be shown mathematically that if strain is

determined in three separate directions from or around a given point on the surface of a stressed body, then the principal stresses and directions may be found algebraically.\* The electric strain gage rosette, therefore, is a suitable configuration for finding the quantities  $f_P$ ,  $f_Q$ , and  $\theta$ .

A remarkably effective method of determining these principal stresses and their angular position on a body subjected to two-dimensional stress can be achieved by graphics, using a method devised by K. J. Bossart, chief of structures of Consolidated Vultee Aircraft Corp.

**Procedure**—The necessary steps to solve for the principal stresses and directions are summarized as follows:

1. The strain gage readings of each leg of the rosette are determined as  $e_1$ ,  $e_2$ , and  $e_3$ , the subscripts referring to the numbered leg of the rosette shown in Fig. 1. Compressive strains are negative (-); tension strains (extension) are positive (+).

2. The magnitude of *apparent* stresses in the direction of each gage axis is determined; that is, the recorded axial strain of each gage is multiplied by the modulus of elasticity for the

\*Those mathematically inclined may consult an article by the present author in *Aero Digest* for Jan. 1, 1945, p. 91, for the demonstration.

<sup>†</sup>Explained in any good book on mechanics, for example, Timoshenko's "Theory of Elasticity".

<sup>†</sup>For differentiation of hydrostatic strain, shear strain, and simple combinations of the two see the first article by the present author in *Metal Progress*, July 1945, p. 91.

metal comprising the structure under load. Thus:

$$f_{\alpha_1} = \mathbf{E} \cdot \mathbf{e}_1; f_{\alpha_2} = \mathbf{E} \cdot \mathbf{e}_2; f_{\alpha_3} = \mathbf{E} \cdot \mathbf{e}_3$$

where  $f_{aN}$  = the apparent stress on a plane perpendicular to the gage axis

$e_N$  = axial strain recorded by the gage, in./in.  
 E = modulus of elasticity of the material, psi.

3. Each apparent stress is divided by 2.

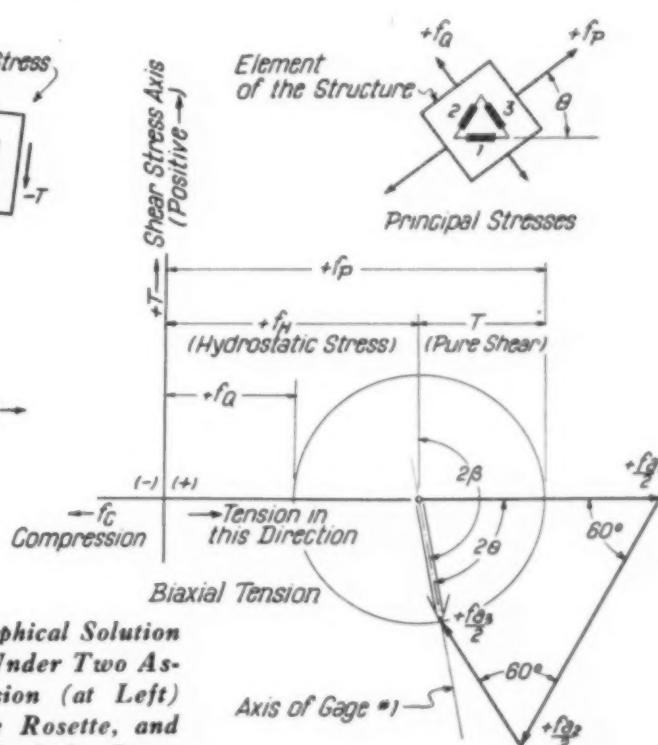
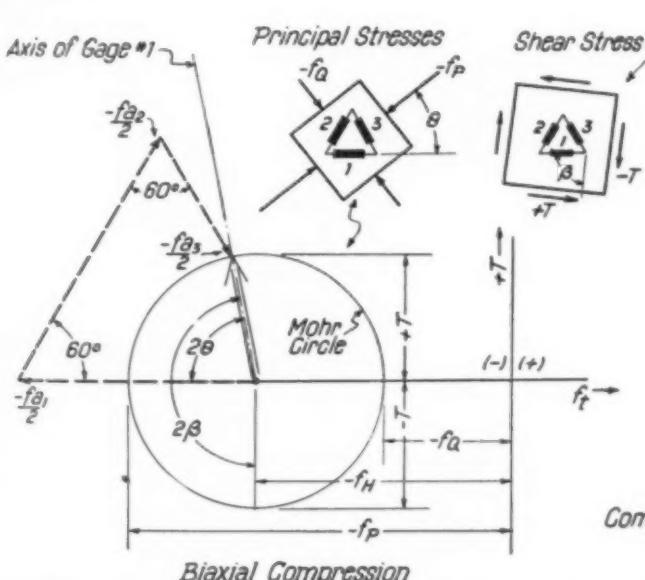
4. The location of the center of Mohr's circle diagram of stress† is the algebraic sum of the half-values of the three apparent stresses:

$$f_H = \frac{f_{a1}}{2} + \frac{f_{a2}}{2} + \frac{f_{a3}}{2}$$

The center of the circle diagram is located to the right of the vertical axis if the summation is positive; to the left if negative (as it is under the conditions assumed at left of Fig. 1). This summation of the apparent stresses, each divided by the factor of 2, equals the hydrostatic component of the state of stress in the structure at the central point of attachment of the strain rosette.‡

5. The radius of Mohr's circle diagram is found as the vector summation of the half-values of the apparent stresses. That is, the value of  $\frac{f_{s1}}{2}$  is laid off along the horizontal axis in the

proper direction (to the right of the center of the Mohr circle if extension, toward the left if compression); at the end of this distance a line (more properly, a vector) at  $60^\circ$ , the direction of strain gage No. 2, is drawn and a distance laid off equal



*Fig. 1—Vector Diagram Showing Method of Graphical Solution for Intensity and Direction of Principal Stresses Under Two Assumed Systems of Loading—Biaxial Compression (at Left) Which Shortens All Three Strain Gages in the Rosette, and Biaxial Tension (at Right) Which Lengthens All of the Gages*

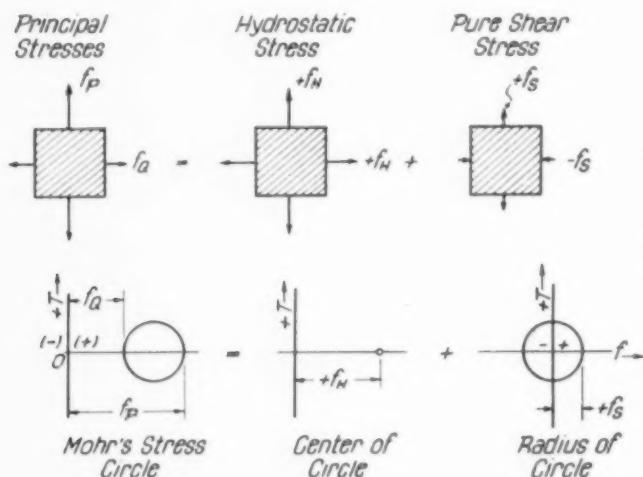
to  $f_{a2}$ ; the same thing is done for gage No. 3.\* The closure line measures the pure shear component of the state of stress in the structure at the point of attachment of the strain rosette.

6. The angle between the axis of gage No. 1 and a principal stress axis is  $2\theta^{\circ}$  on the circle diagram and  $\theta$  in space. The direction of maximum shear stress is located by the angle  $\beta$  and, as shown,  $\beta = \frac{1}{2}(2\theta + 90^{\circ})$ .

7. Any state of two-dimensional stress or strain can be resolved into symmetrical and anti-symmetrical components as explained in the article in *Metal Progress* for July 1945. The hydrostatic stress is the symmetrical component and the pure shear stress the antisymmetrical component of the two-dimensional stress field. Therefore the complete state of stress is determined in either of the diagrams of Fig. 1.

The method outlined may be clarified through the presentation of three illustrative examples.

**Cylinder Wall** An aluminum cylinder, sketched in Fig. 2, is subjected to internal hydraulic pressure and a strain gage rosette is mounted on the outside. A square element is isolated in the wall and the stresses acting upon it are



The strains as measured by the gages are:

$$\begin{aligned} e_1 &= +108 \text{ microinch per in.} \\ e_2 &= +250 \\ e_3 &= +392 \end{aligned}$$

$$\text{whence } \frac{f_{a1}}{2} = +540 \text{ psi.}$$

$$\frac{f_{a2}}{2} = +1250 \text{ psi.}$$

$$\frac{f_{a3}}{2} = +1960 \text{ psi.}$$

$$\text{The sum: } f_h = +3750 \text{ psi.}$$

Using the graphical method in the manner shown in Fig. 2 the major stress  $f_p$  is found to

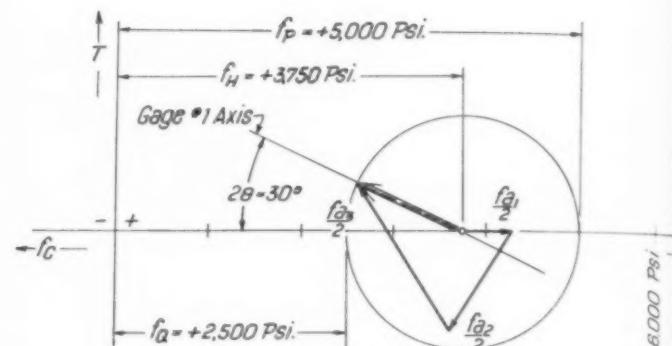
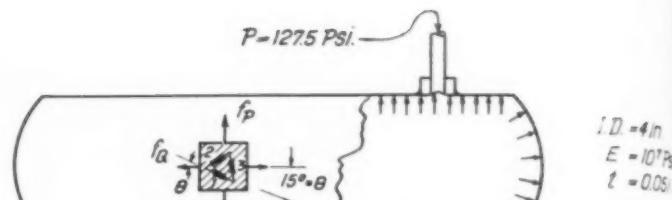


Fig. 2 — Graphic Solution for Principal Stresses in Cylinder Wall

equal  $+5000 \text{ psi.}$ ; the minor stress  $f_0$  is found to equal  $+2500 \text{ psi.}$ ; the angle  $\theta$  between the axis of gage No. 1 and the minor principal stress axis is found to be  $15^{\circ}$ . Since strain gage No. 1 is located so it has an angle of  $15^{\circ}$  with an element of the cylinder, the minor stress is parallel to the longitudinal axis and the major stress is perpendicular thereto. Furthermore:  $\frac{p \times D}{2t} = f_p$

where:  $p$  = hydraulic pressure inside cylinder  
 $D$  = inside diameter of cylinder, in.  
 $t$  = thickness of cylinder wall =  $0.051 \text{ in.}$

$$\text{whence } p = \frac{5000 \times 2 \times 0.051}{4} = 127.5 \text{ psi.}$$

### Landing Gear Axle

The juncture of the axle and piston of a landing gear strut forms a curved steel beam as shown in Fig. 3. To determine the stresses at point A, an equilateral strain gage rosette is mounted at the center of the concave surface. At a given load of  $P$  lb. the readings of the individual legs of the rosette are listed at top of the next column.

\*The direction along this second line or vector may be confusing. Note, however, in Fig. 1 that in starting this summation the vector for gage No. 1 is always laid off along the X axis; compression to the left; tension to the right. If all vectors are of the same sign, they always add in a clockwise manner; any vector or vectors differing in sign from the preceding vector is laid off in a direction  $180^{\circ}$  diametrically opposite to the position it would have taken if it had had the same sign as the preceding vector.

$$e_1 = -2000 \text{ microinch per in.}$$

$$e_2 = -4660$$

$$e_3 = -3330$$

$$\text{whence } \frac{f_{a1}}{2} = -30,000 \text{ psi.}$$

$$\frac{f_{a2}}{2} = -70,000$$

$$\frac{f_{a3}}{2} = -50,000$$

$$f_h = -150,000 \text{ psi.}$$

which locates the Mohr circle.

The state of stress at the point A of the axle is found, graphically as shown in Fig. 3, to be described by a major stress of 185,000 psi. compression and a minor stress of 115,000 psi. compression, while the angle between gage No. 1 and the minor principal stress is 14.5°.

**Airplane Wing** — The wing sketched in Fig. 4 has a main beam composed of a thin shear web and heavy caps. The dimensions of the beam are such that the shear web buckles at a comparatively low applied load and the greatest share of the transverse loading must finally be carried by diagonal tension stress in the web. The beam described is known as an "incomplete tension field" beam. The principal stresses and directions in this type of beam are very difficult to predict and the stresses cannot be determined with exactitude except by electric strain gage analysis.

Before loading the wing, two equilateral strain gage rosettes were cemented to the shear web as shown in Fig. 5. The first rosette was cemented to the face of the web and the second rosette was carefully located on the other side of the sheet directly behind the first. The function of the second rosette is most important, for it must be used to cancel out the secondary strains

Fig. 4—Sketch Showing Location of Beam Shear Web in Airplane Wing and the Approximate Location of Its Principal Stresses

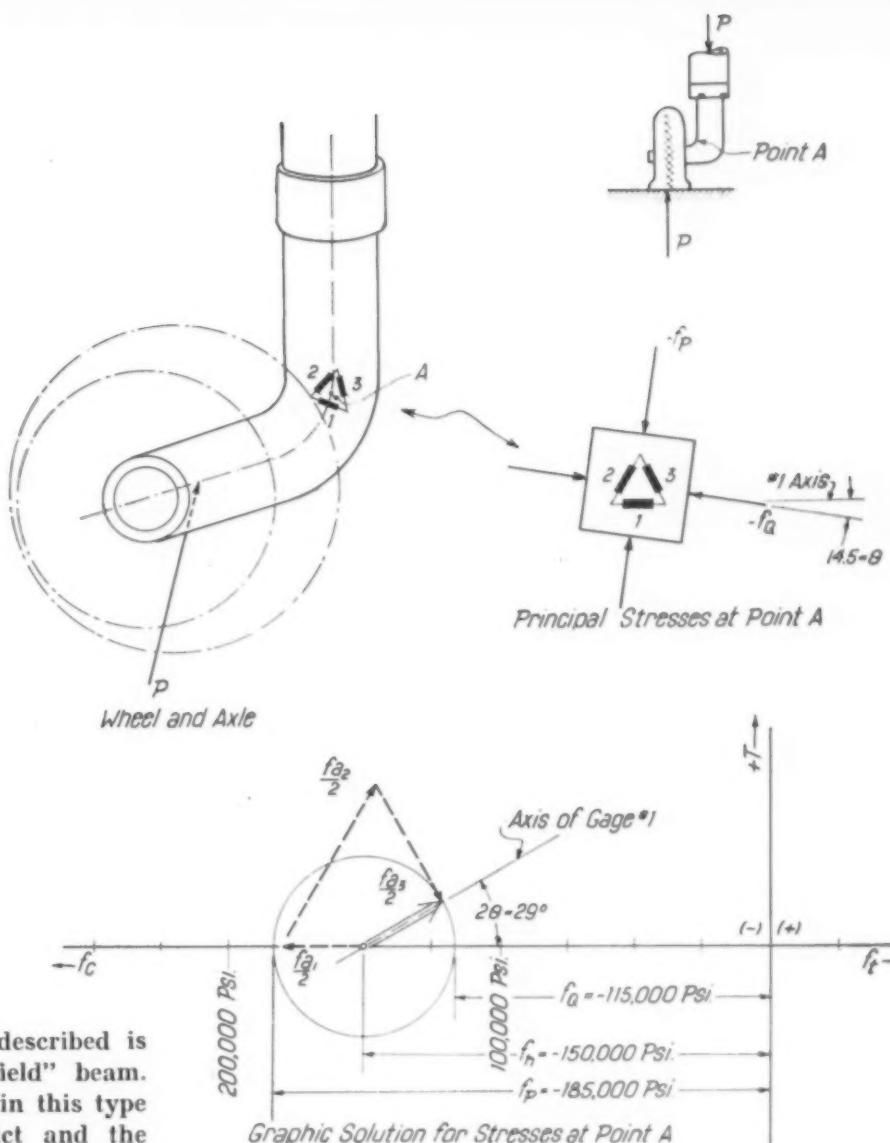
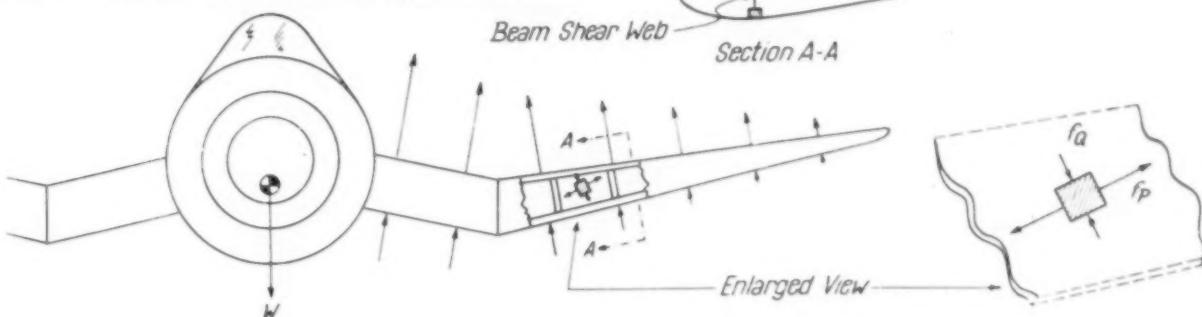


Fig. 3—Stresses in Airplane Landing Gear Axle

due to the buckling of the web. To obtain the average strain throughout the thickness of the shear web it is necessary to take readings on both sides of the sheet or plate. For any given direction, the average of these two strains, front and back, yields the average strain across the sheet.

It is possible, using the separate rosettes, to solve independently for the stresses on both sides of the sheet and then obtain the average of a vector

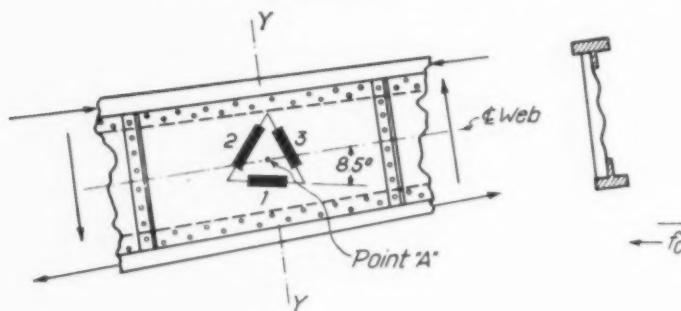
summation of the two stress states, but such a procedure is quite difficult. It is better to obtain the average strains in the sheet for each leg of the rosette by averaging each leg of one rosette with the corresponding leg of its backing rosette. The average strains so obtained may then be used to obtain a ready solution of the average or axial stress state in the sheet. (A frequent source of error lies in the misalignment of the front and back gages, and sometimes the wiring is carelessly mismatched with the result that the data cannot be analyzed.)

In the incomplete tension field beam of the wing at a given load the averaged readings of each leg of the rosette were:

$$\begin{aligned}e_1 &= +400 \text{ microinches per in.} \\e_2 &= +753 \\e_3 &= -500\end{aligned}$$

The modulus of elasticity of the 24S-T alclad is  $10.3 \times 10^6$  psi., so the half apparent stresses are

**Fig. 5—Graphical Solution of Principal Stresses in Buckled Shear Web, and Estimation of Shear in Direction Y-Y, Normal to the Web's Center Line**



+2060, +3875 and -2575 psi. respectively, and the algebraic sum  $f_b$  equals 3360 psi.

Using Bossart's method illustrated in Fig. 5, the principal stresses are found to be:

$$\begin{aligned}f_p &= +9200 \text{ psi.} \\f_q &= -2550 \text{ psi.} \\&\theta = 37^\circ\end{aligned}$$

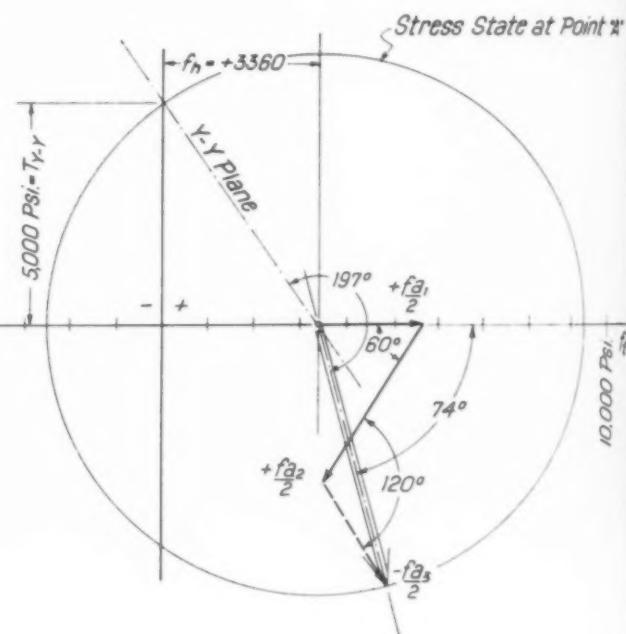
The difference in sign of the two principal stresses reveals the fact that the web has buckled under compression (the minor principal stress) and provides a measure of the amount of the transverse shear carried by the tension field. In this particular application it is known that the transverse shear stress in the web on plane Y-Y, Fig. 5 (perpendicular to the web's center line), is 5000 psi.; plane Y-Y is twice  $98.5^\circ$  or  $197^\circ$  in a counterclockwise direction on the Mohr's circle diagram from the axis of gage No. 1.

The shear stress on the Y-Y plane is found in Fig. 5 to be 5000 psi., and this scaled value checks

exactly with the known transverse shear stress.

**Curved Panel With Rectangular Duct**—An excellent proof of the efficacy and validity of the strain gage rosette is found in the examination of the buckled, curved shear panel containing a rectangular duct shown in Fig. 6. A sketch of its contour, edge-on, is at the left of Fig. 7. This is half of the fuselage of the XP-81, the cut-out for the jet intake accounting for the peculiar shape.

In this type of analysis the skin is assumed to resist all of the transverse shear loading due to air loads on the tail or other causes. The skin is assumed to have no resistance to bending moments. Conversely, heavy extruded caps located at five places (No. 1 through 5 in Fig. 7) are assumed to resist all of the bending loads and none of the shear loads. Following these assumptions the shear stress in the fuselage side-wall should follow the formula  $SQ = It$ , and as we shall see it does quite well. In Fig. 7 the circled areas



are proportional to the effective area of the extruded caps located there to resist bending load.

For test purposes the panel was fixed securely all along either edge to the steel plates at the left and right of Fig. 6, and loaded by hydraulic jack pressing upward on one of these plates while the other was held rigidly to a vertical column. Total shear load was 40,000 lb.

Figure 7 shows the shear stresses computed on the assumption that bending resistance is concentrated at the five locations (No. 3 and 4 being treated as one, since they are close to the neutral axis). The diagram also shows values derived from the rosettes cemented on the sheet (fore and

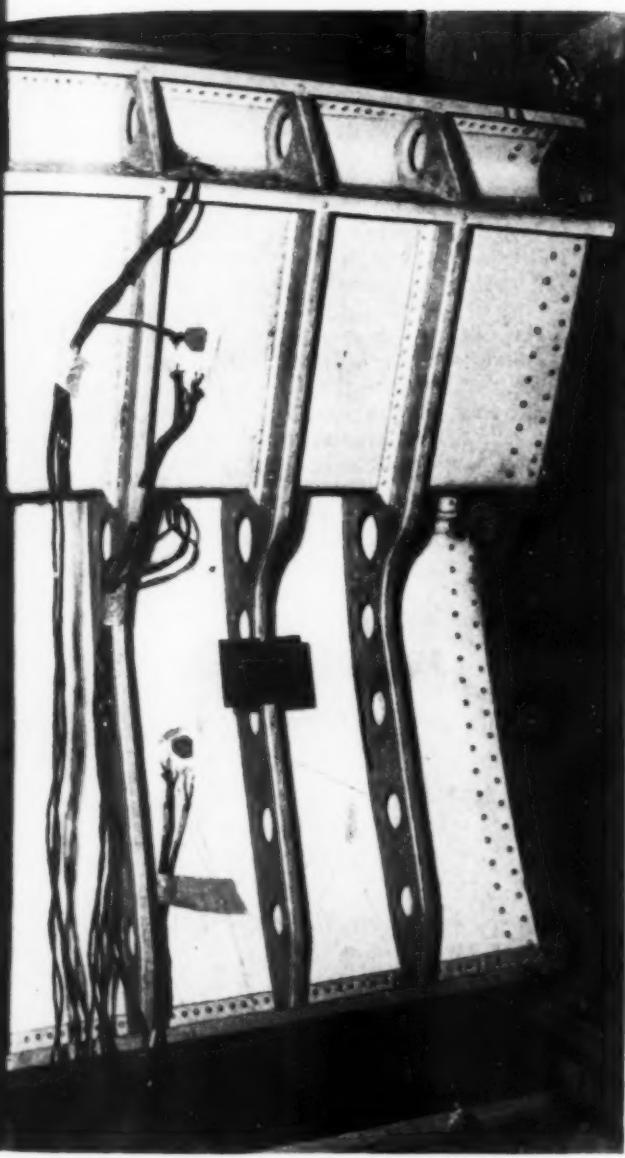


Fig. 6 — Curved Shear Panel, Wired for Test

aft) as shown on the photograph and located at A, B, C and D in Fig. 7. Agreement is excellent:

LOCATION	COMPUTED	ROSETTE
A	8,700 psi.	8,600 psi.
B	12,900	14,000
C	12,900	13,600
D	12,600	12,600

**Necessary Refinements** — In such a general account as this it is undesirable to complicate matters by discussing certain refinements required for results of high accuracy. It might be mentioned, however, that Bossart's graphical method described above was derived on the assumption that Poisson's ratio,  $\mu$ , for the material under study is equal to 1/3. In some instances the value of  $\mu$  is appreciably different from this fraction.

Likewise, due to this same property of materials under strain, the loops at the ends of the wires comprising the electric strain gage undergo small compressions when the gage measures simple axial tension (and *vice versa*). Commercial gages are calibrated by the manufacturer in simple axial tension and the effect of cross sensitivity is absorbed by the overall factor noted on each gage. In this manner the cross sensitivity factor is disguised. In applications involving two-dimensional stress fields the ratio of axial to normal strain differs from the ratio existing in simple tension and as a consequence some error will be encountered unless the final results are corrected for the cross sensitivity of the gages.

To correct the circle diagram of stress for the combined effects mentioned above, the following equations for true center and true radius may be used:

$$\text{True center } f_h = f_{ha} \left( \frac{0.6667}{1-\mu_t} \right) \left( \frac{1-0.285 F}{1+F} \right)$$

$$\text{True radius } f_s = f_{sa} \left( \frac{1.3333}{1+\mu_t} \right) \left( \frac{1-0.285 F}{1-F} \right)$$

where  $f_{ha}$  = apparent hydrostatic stress derived from Bossart's method, assuming  $\mu = 1/3$

$f_{sa}$  = apparent pure shear stress derived from Bossart's method assuming  $\mu = 1/3$

$\mu_t$  = actual Poisson's ratio for the material under test

F = cross sensitivity factor of gage.

These corrections having been made, the other steps in the graphical analysis are as outlined at the outset.  $\diamond$

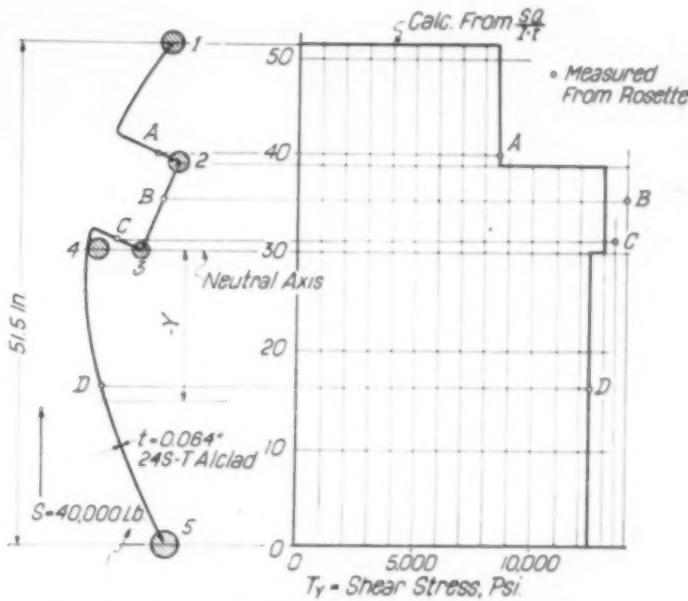


Fig. 7 — Diagram Showing Simplified Assumptions Prior to Computing Shears in Curved Panel, and a Diagram Comparing Computed and Experimental Values of Shear Stress

# Peace in the Atomic Age

By Leo Szilard\*

AS far as I can see, I am not particularly qualified to speak about the problem of peace. I am a scientist and science, which has created the bomb and confronted the world with a problem, has no solution to offer to this problem. We know that Nagasaki-type demolition bombs could be produced in large quantities; but 10 or 15 years from now giant bombs which disperse radioactive substances in the air may be set off far away from our cities; the buildings would remain undamaged, but the people inside of the cities would not remain alive.

With the United States and Russia far outranking in military power all other nations, no "balance of power" in the original meaning of the term is possible. Because of the possibility that they *might* be at war with each other at some future time, these two governments consider it their duty to put their nations into the position of winning that war if war should come. Stated in these terms, the problem is not capable of a solution which is satisfactory to both parties.

How do atomic energy and the bomb fit into this picture? Atomic bombs may be the only effective weapon by means of which Russia could carry war to our territory. Clearly, this is good and sufficient reason for the United States to try to eliminate atomic bombs from all national armaments. But can we see clearly for what specific reason Russia should be expected to concur? We must seek the reasons which might, nevertheless, move Russia to agree to some effective control.

It is easy to agree that permanent peace cannot be established without a world government. But agreement on this point does not indicate along what path that ultimate goal can be reached in time to escape another world war. Any agreement in this field will have to be regarded more as a voluntary arrangement than an enforceable obligation. Under such circumstances the question of incentives becomes the predominant question. The United States has obviously strong incentives for maintaining an arrangement that will eliminate atomic bombs from all national armaments. Therefore the question is the incentives Russia should have to keep such an arrangement in force.

It seems to me that this could be satisfied only within the framework of an organized world community, with a number of agencies. The agencies which I have contemplated would operate on a budget of about 20 billion dollars per year.

They might move, in the next 20 years, in amounts of two to four billion dollars per year, farm products from the United States to industrial countries unsuitable for agriculture.

They might build up a vast consumers' goods industry in a number of countries, including Russia.

They might lessen the economic insecurity of nations by purchasing large quantities of raw materials from these nations during depressions and by selling these materials from stock during booms.

They might enforce peace by maintaining an armed force strong enough to restrain from illegal action most of the nations but not strong enough to coerce the United States or Russia.

They might be given the right to place, say, up to 20% of "foreign" students into the colleges

of any one country and would pay for their tuition and living expenses. Moreover, 20% of the "foreign" students who graduate in any one country might be given the right to settle in that country.

Another agency might be delegated the task of giving access to "information" to everyone everywhere in the world by having jurisdiction over one page of every newspaper in the world.

The obstacles to plans of this sort are obviously great but such plans can be kept within the realms of practical possibilities if we clearly recognize the present limitations. We cannot give to such agencies the responsibility of maintaining full employment throughout the world; we must not expect to cope in the next 20 years with raising the standard of living everywhere in the world; we cannot open the door for large-scale migration.

This does not mean that the countries who may receive help in the next 10, 15 or 20 years shall receive gifts without assuming obligations. These countries ought to have precisely the same obligation as the United States to contribute to the development of the world up to 10% of their national income. There is little reason for expecting any of the countries who would receive help to display gratitude. Nor is there much reason for looking upon our own contribution as anything but evidence that at last we have made up our minds to do our duty by the world.

Within such a framework Russia might receive, on the basis of objective needs and available resources, perhaps five billion dollars per year. No sane person can believe that we are solely concerned about winning the next war if we are spending a substantial fraction of our national income for the welfare of those countries who would most likely be our enemies in case of war.

Some of these agencies would be more acceptable to the Russians than others, but a world community cannot be built by reaching agreements piecemeal and the whole pattern of agencies, properly balanced, will have to form a single package, which provides for at least the first steps toward a universal bill of rights. Just when and in what circumstances such a package might be acceptable to Russia is a crucial question.

Most of us physicists believe that nothing short of a miracle will bring about such a peaceful solution. But a miracle was once defined by Enrico Fermi as an event which has a probability of less than 10%. Obviously the odds are heavily against us but we may have one chance in ten of reaching safely the haven of permanent peace; and maybe God will work a miracle—if we don't make it too difficult for Him.

\*Extracts from an address on international aspects of atomic energy given before a conference of scientists at University of California late in April, and expanded into an article for *Saturday Review of Literature*. Dr. Szilard is professor in the Institute of Radiobiology and Biophysics at the University of Chicago. As to his foresight in matters concerning atomic fission, the following from the "Smyth Report" may be quoted: "The early efforts at getting government support [for studies on the possible military use of the energy released in fission] were stimulated largely by a small group of physicists centering on Leo Szilard." This movement started in the spring of 1939.

Notes on a lecture for the 1946 educational program of the Birmingham District Chapter  $\odot$ . The demands for war material

and ordnance posed many new problems to the foundryman, and upset his conventional ideas as to market, quality, inspection,

materials. The resulting changes in practice forced upon him will affect peacetime output, markets, and competitive uses.

## ADVANCES IN THE FOUNDRY INDUSTRY

By CHARLES K. DONOHO

American Cast Iron Pipe Co., Birmingham, Ala.

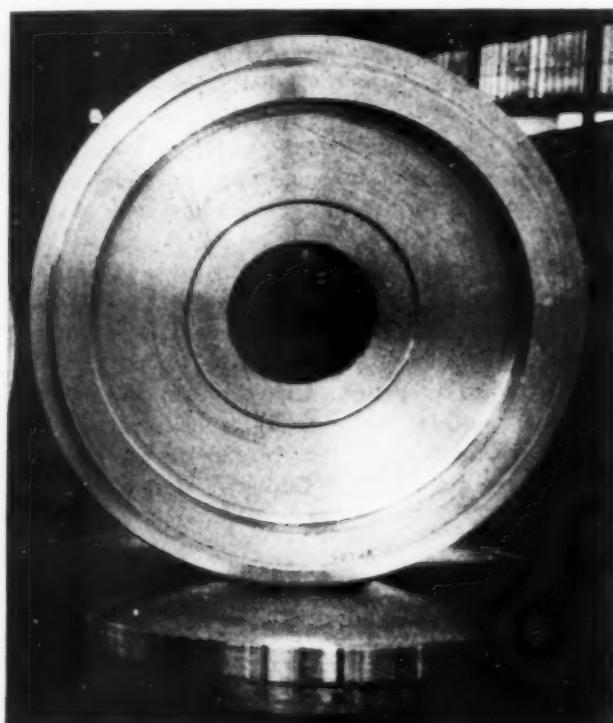
Fig. 1—Centrifugal-Cast Flywheel of Steel, 20 In. Dia.

many entirely new applications. In the field of gray-iron and malleable castings, the curtailment of standard peacetime uses caused the development of new and different applications which normally would not have been brought about for years. The net result of these dislocations, trying as they were, has been to bring about new uses for castings and to accelerate standardization of production techniques.

**Mechanization**—Due to its ancient heritage, foundry practice has remained more an art and less a science than many newer operations. Consequently, there has been, and is, a most fertile field in the foundry for the application of modern mass production methods. Contributing to the mechanization of the foundry are many recent installations of sand handling systems, molding machinery, conveyer lines, mechanical shakeouts, improved blasting and cleaning equipment, sand reclamation systems, continuous melting methods, and modern mechanized heat treating equipment. These increase the over-all efficiency of production and make the foundry a more attractive place in which to work. Mechanization constitutes the most important single advance of the industry; although it started 30 or 40 years ago, at present we have made a mere beginning.

**Inspection**—Testing, inspection, and quality control are closely interrelated, since each supports the others. Necessarily strict specifications for castings going into new services have required many plants to make tests and meet demands

THE VARIOUS ELEMENTS of the foundry industry, in common with other American industries, underwent many violent readjustments during the war and reconversion periods. For example, there was an unprecedented demand for light-metal and steel castings during wartime. This forced a rapid development of mass production methods in these plants to increase output. Shortages of forging capacity forced castings into





*Fig. 2—Alloy Steel Cylinder Barrels, A.M.S. 5345 Specification, Centrifugal-Cast in Metal Molds or Dies. Illustration shows barrels after machining*

which were entirely new. This had the salutary effect of bringing testing equipment into the foundries, as well as technicians to make and interpret the tests. New, rapid and accurate analytical methods, and mechanical testing for quality, facilitate the making of quality castings.

Besides testing for metal quality, inspection of the castings themselves has improved. Radiography and magnetic particle testing have been particularly valuable in preventing the shipment of a faulty product. Proof stressing or other simulated service tests on the castings themselves are replacing test-bar tests in many instances.

When the advanced testing and inspection methods are applied to the raw materials as well as to the products, we are well on the way to quality control and uniform, standardized foundry processes.

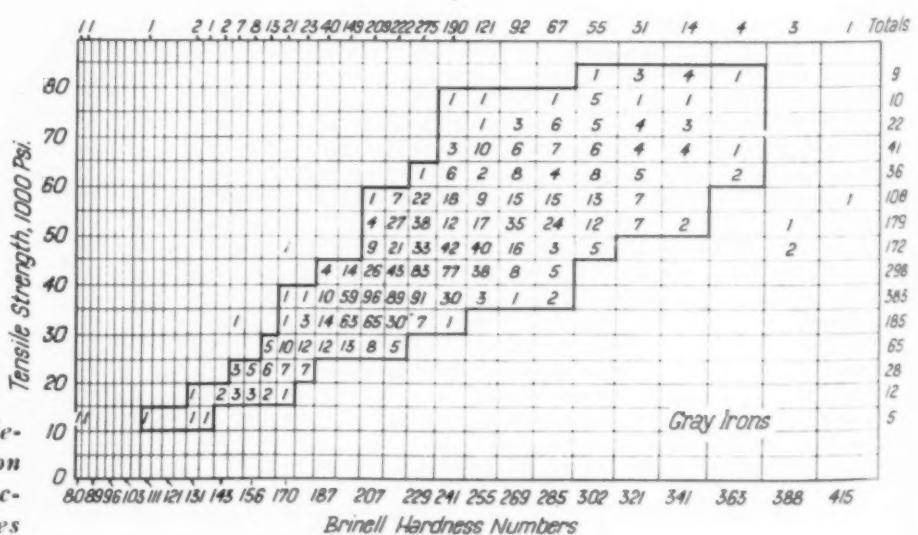
**Advanced Casting Methods**—The application of the lost-wax method of

investment casting to produce complex engineering parts to close tolerances has proved to be a real advance. The economic applications of this method are chiefly in shapes difficult to form by any other method, or in metals which are commercially unmachinable. The lessons learned in precision casting—close cast tolerances and fine finishes—may be expected to be applied gradually to the production of grosser parts.

Die casting or metal mold methods also produce parts of good finish and to close tolerances. These methods are practically the standard for many zinc-base and aluminum alloys, but are also used for large tonnages of gray-iron castings—and recently in some vol-

ume for bronze and steel castings. Metal and graphite as mold materials, instead of the foundryman's time-honored sand, are finding their place in mass production.

Centrifugal casting has continued to find new applications in the last few years. By centrifugal force we may exert selective pressure on freezing metal to separate the dense clean metal from the lighter slag and dross. Gray iron and bronze are favorite metals for centrifugal casting, and recently much high quality steel has been cast centrifugally both in cylindrical shapes and into



*Fig. 5—Gray Iron Is Still the Tonnage Foundry Metal. Photograph shows a train load of centrifugal-cast pipe of fairly large diameter*

disk-shaped parts. Figure 1 represents one type of such work, rather large in dimension. High-alloy tubing for heat resistant retorts was cast centrifugally in great quantity during the war, adapting the mechanical casting operations long practiced for cast iron pipe.

These advanced casting methods are often combined. Centrifugal die casting is used to form aircraft-quality, alloy steel cylinder barrels, as shown in Fig. 2. In lost-wax or "precision" work, centrifugal casting is a favorite method of obtaining pressure on the liquid metal to insure the complete filling of the mold.

### Gray-Iron Castings

Gray iron is by far the largest tonnage foundry metal (Fig. 5). As compared to steel, its lower freezing range and smaller shrinking tendency make it one of the better casting metals. The metallurgy of cast iron is complicated by the presence of carbon in three forms—free, combined, and dissolved—which vary in their relative proportions with composition and thermal history. The variety of types of gray iron, from bath tubs to crankshafts, makes it difficult to set down rules for gray-iron casting.

The evaluation of "carbon equivalent" of cast iron, usually taken as  $\%C + 0.3(\%Si + \%P)$  is useful to establish the position of an alloy in its relation to the iron-carbon eutectic, which is at about 4.30% carbon. "Degree of saturation", used in Europe for the same purpose, is given by Brinkman and Tobias in *Die Giesserei* for Sept. 18, 1942 in the formula at top of the next column.



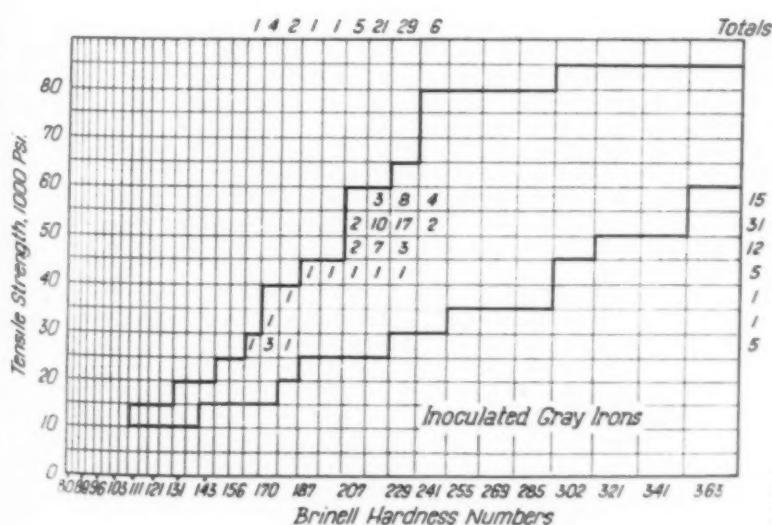
% C

% Saturation =  $4.23 - 0.312\% Si - 0.33\% P + 0.066\% Mn$

It will be noted that this formula uses nearly the same constant and coefficients as the American "carbon equivalent", but introduces the additional factor for manganese.

In a given section, a casting will be progressively softer and weaker as 100% saturation is approached and, of course, hypereutectic if more than 100% saturated. Either of these formulas enables the foundryman to evaluate one type of iron against another, and to reconcile widely varying analyses with the properties to be expected.

There are appreciable variations of gray iron's properties; however, even with identical carbon equivalents. The most desired combination for engineering castings is usually maximum strength and minimum hardness. Therefore the relation between tensile strength and Brinell hardness is a valuable indicator of quality. J. T. MacKenzie recently published an exhaustive study of tensile-Brinell relations in gray iron (see *The Foundry* for October 1946). Figure 3



*Fig. 4—Tensile-Brinell Relations: 70 Tests on Inoculated Gray Irons (MacKenzie)*

(from MacKenzie's work) shows 1553 tests on gray irons plotted on a frequency basis. The irons with the desirable combinations of strength and machinability are those lying high and to the left in such a diagram.

A valuable metallurgical technique for increasing the quality and consistency of gray iron is inoculation. It has been proved that the



addition of a graphitizing alloy or "inoculant" to molten iron in the ladle has a stronger effect than if the same increase is made by addition of the alloy to the solid charge before melting. Useful inoculants include silicon, carbon (graphite), zirconium, calcium, aluminum, titanium, and combinations of these with or without other alloys. The principal effects of inoculation, all of which are generally beneficial, are to reduce chill and

hard spots, to produce a normal flake structure of graphite in the pearlite, to reduce section sensitivity, and to increase the strength-hardness ratio. Figure 4 shows a group of inoculated irons plotted on the same chart as used for Fig. 3, illustrating how inoculation gives an iron of consistently high quality in the last-mentioned respect.

The relation of gray-iron structure to service properties is becoming better understood. For good wear resistance in engine cylinder iron, a normal graphite structure with pearlite matrix is desirable. For resistance to wear and heat shock, as in brake drums, the cushioning effect of high graphite is beneficial.

Fig. 6 — *Effect of Residual Aluminum on Medium Carbon Steel, Cast in Sand With 5% Moisture. Plates are 2x4-in. area, tapered from  $\frac{1}{2}$  to  $\frac{3}{4}$ -in. thick, cast flat with no feeding. Bottom has no aluminum; middle has 0.01% residual; top (with normal shrinkage) has 0.03% residual aluminum*

### Steel Castings

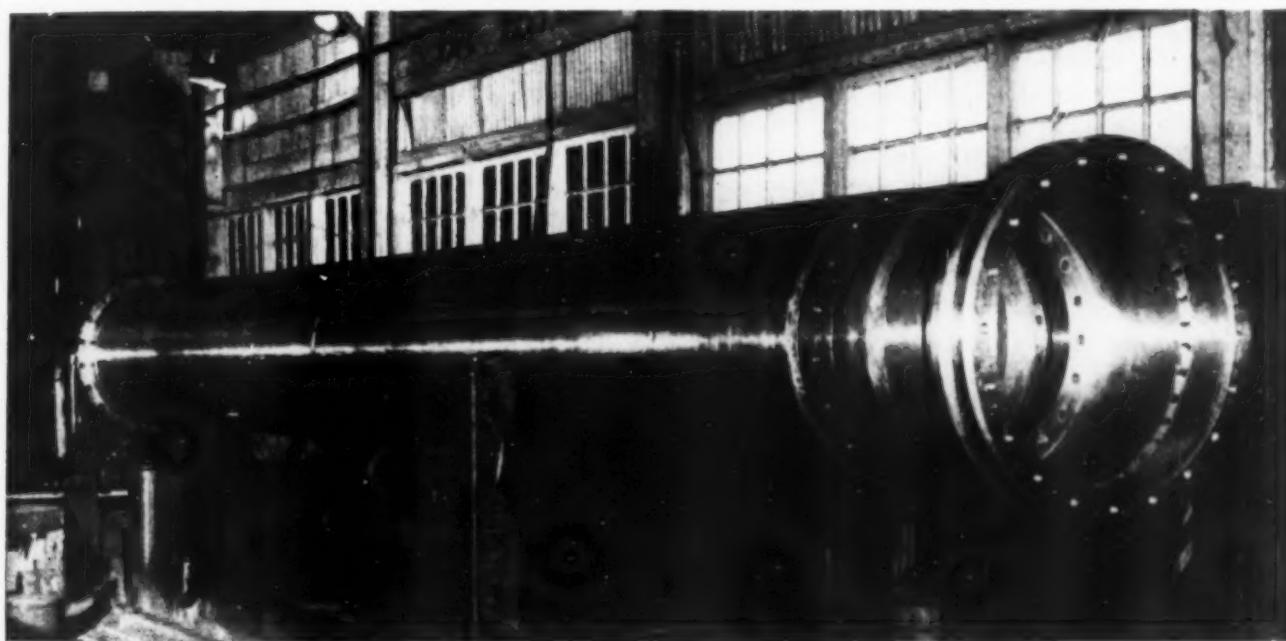
Steel for castings is melted in many types and combinations of units. A contribution to higher production during the war was made by the converter, usually in conjunction with an electric holding and refining furnace. The idea that good quality steel cannot be made in the side-blown converter was largely dispelled. Deoxidation of molten steel for castings has also received critical attention. The melting practice and necessary deoxidation (usually with aluminum) to eliminate pinholes positively in green sand castings have been better established (Fig. 6); a somewhat detailed discussion of this entire problem was presented to The Electrochemical Society by Sam F. Carter and C. K. Donoho ("Acid Electric Steel for Castings", preprint 91-12, April 1947).

Sound, tough castings depend on a complex interplay of chemical and mechanical factors; five of the former are dissolved oxide, oxide inclusions, sulphide inclusions, dissolved hydrogen and dissolved nitrogen. While it is known that an effective "carbon boil" tends to remove these gases, present knowledge has not explained adequately how hydrogen and nitrogen get back into the metal between the boil and the final casting. It is probable that more importance should be attached to *conditions of exposure*, rather than degree of exposure. The best melting practice may be a compromise rather than a concentrated attack on a single one of the detrimental constituents.

Studies of such complex relationships require

the analysis of many similar heats. The paper mentioned above included such a study. From 120 heats of 0.25% C, 0.65% Mn, 0.45% Si steel, evaluated for quality by the "P factor", the ten best heats ( $P=78$  to 85) and the ten poorest ones ( $P=43$  to 62) were compared. Minor variation of the common elements gave no clue to the differences. The better uniformity of aluminum residual in the best heats emphasized the importance of aluminum control; the slag fluidities of the poor heats also varied over wide limits. Most significant of all was the predominance of certain deoxidation sequences in the best heats, and of other sequences in the poorest heats.

*Fig. 7—Reaction Vessel Fabricated of 25% Chromium, 20% Nickel Heat Resisting Alloy by Welding Together Centrifugal-Cast Tube Sections and Static-Cast Flanges. Dimensions: 34 in. outside diameter, 1-in. wall, 27 ft. long, weight 13,000 lb.*



The state of knowledge in the steel castings industry about alloying and hardenability control has followed closely the remarkable developments in rolled steel. The timed water quench has given the steel foundryman a practical heat treatment for the mass production of quality parts. The control of hardenability by composition and its quick determination by the end-quench test, together with the segregation (for heat treating) of castings of like section, the timed water quench followed by an air cool or immediate tempering, can produce uniformly hardened and tempered structures without danger of cracking, even when the shapes are quite complex.

In the high-alloy stainless or heat resisting

steels the metallurgy and properties peculiar to castings as differentiated from rolled products have been studied extensively. This phase of the industry seems particularly promising, as many of the metals involved are quite difficult to roll or forge, yet may be readily and economically cast. Likewise the cast structure seems to be more favorable for resistance to stresses at high temperature than the finer grained more homogeneous structure in rolled plate or forgings. Figure 7 shows an instance of where castings, welded together, have formed a very large reactor of 25-20 Cr-Ni alloy.

In steel founding the general recognition and application of the principle of "controlled direc-

tional solidification" has produced radiographically sound castings consistently. Recognizing that shrinkage must inevitably occur when molten steel is poured into a mold, the problem resolves itself into arranging the gates and risers so that risers are the last to freeze, and the shrinkage occurs outside the useful part of the casting.

A thin, flat core with a small aperture at the junction of riser and casting, shown in Fig. 8, is useful to facilitate riser removal and to reduce grinding costs. For a given core thickness the diameter of the opening must be larger than a certain critical diameter to obtain proper feeding of molten metal from the riser. The dimensional relations necessary for proper functioning of such

*Fig. 8—Flat Core, Producing Necked Riser. Proportions are correct for casting of 2-in. section; neck must be short enough so it will not freeze before riser has functioned to feed shrinkage in the casting below*

necked-down risers have now been soundly established.

#### The use of graphite rods to break the skin

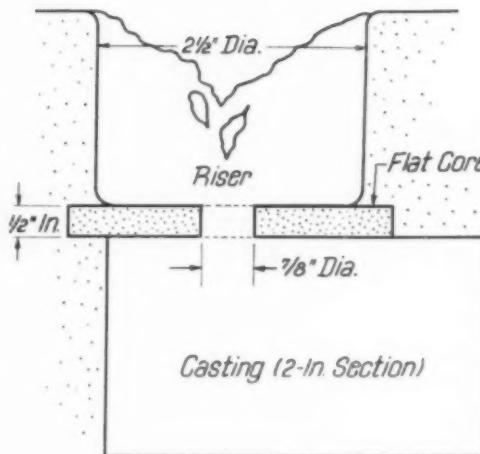
of blind risers, and the addition of exothermic materials on top of risers, both increase the percentage yield. Exothermic or insulating materials for reducing the freezing rate, and chills for increasing the freezing rate, are two tools which are used for positive control of solidification in a casting so that freezing progresses directionally.

Maximum yield of castings in proportion to steel melted depends upon using the smallest volume of risers which will just feed the casting. Progress is being made toward establishing the definite mathematical relations of volume and surface for maximum riser efficiency.

#### Malleable and Nonferrous Castings

Malleable iron metallurgy is trending toward lower carbon contents, many analyses approaching those of graphitic steel. This increases both strength and ductility—a concomitant trend peculiar to malleable iron. Continuous annealing equipment gives better control of heat treatment and shorter annealing cycles. The very interesting properties of the pearlitic malleables are being exploited commercially on an increasingly large scale. During the war the combination of toughness and machinability of malleable iron castings was rediscovered for ordnance parts where fast machining was a prime requisite.

Some interesting malleable iron products are being made by die casting; one such is illustrated in Fig. 9. Iron much higher than ordinary in silicon



content can be cast white in metal molds, with consequent shortening of the annealing cycle. An austenitic malleable iron, cupola melted and die-cast, shows interesting possibilities.

In brass and bronze foundries melting practice to produce gas-free metal has been studied intensively. Centrifugal casting has also been highly developed for bronzes to produce bearings and bushings of superior properties and soundness.

Aluminum and magnesium casting, of course, increased tremendously in quantity during the war and opened up a vast new phase of the foundry industry. Although the age-old problems of casting metals to shape are always the same, there are many special techniques for handling light metals which are unique to that branch of the industry. Space does not permit their discussion now.

#### Summary

In evaluating generally the advances which have been made in the foundry industry there is an implicit emphasis on the advances which are yet to be made. Although much progress has been made, it is at once discouraging and heartening to realize our ignorance, and to be aware of the still limitless possibilities for improvement in the arts and sciences of casting metals.



*Fig. 9—Die-Cast, Malleable Iron Bolts for Pipe Joints*

Some metallurgical and design details showing how the spring designer and spring maker have combined the advanced knowledge of elastic action in hard-

ened and overstressed steel to improve greatly the operating characteristics of heavy, track-laying vehicles, such as tanks and gun carriages. Independent

suspension of every wheel by such means has much to recommend itself for peacetime uses in heavy trucks, busses, and railroad rolling stock.

## TORSION BAR SPRINGS

SPRINGS are more or less mysterious to the mechanic, as well as the engineer, because they act in a manner apart from practically all other machine elements, changing their shape greatly and designedly, rather than stoutly and rigidly resisting the loads. Nearly all engineering constructions are designed as static structures; only in the largest bridges, for example, is the possibility entertained that the length of principal members (and consequently the shape of the structure) will be different under the heaviest loadings. Probably this esoteric action is responsible for the circumstance that springs are too frequently chosen on the trial-and-error basis, and the men who make springs, and who really should know *why* they make them thus and so, with some notable exceptions rely upon tradition in their production methods rather than mechanics and metallurgy.

It is therefore worth while to put on record some facts now available about the so-called "torsion spring" used toward the end of the war for wheel suspensions on tank destroyers, tanks, and other combat vehicles of the track-laying type. It was a combined achievement of men who could analyze the requirements of a heavy vehicle going at high speed over rough ground, engineers who knew the nature and location of the stresses in the shock absorbing parts and how to design them safely for expected life, metallurgists who knew how to produce the right steel and treat it so it had correct gradation of properties surface to center to sustain the working stresses, and production men who delivered the unusual parts in required number.

It is not only one of hundreds of records of wartime teamwork, it is also one of hundreds of

examples where peacetime developments in several different arts and sciences were coordinated to solve successfully a major wartime problem. Likewise it is possible that torsion springs will be extended from war equipment to heavy high speed trucks and busses (some prewar European trucks were using them) and also -- who knows -- to railway coaches as well.

But first, what is "torsion bar suspension"? It can be visualized by imagining that the wheel axle, instead of running clear across the vehicle's chassis and being attached thereto by flexible members (springs and shock absorbers), is merely a perpendicular lug on the end of a Z-shaped lever or support arm. The other end of this lever arm is keyed to the outboard end of the torsion bar, and this torsion bar itself extends clear across the vehicle as a true axle would, and is rigidly fixed to the chassis at the far or inboard end. The outboard end of the torsion bar -- or rather a heavy sleeve surrounding it -- operates in a pair of needle bearings, and the wheel's movement is therefore guided, by the support arm acting as a radius bar, in a circular arc. This relieves the torsion bar of major bending stress imposed by any bump against the wheel coming from a longitudinal direction; vertical movement of the wheel obviously twists the torsion bar. The design, metal, and its production history, are such that the maximum twist is less than the elastic limit in torsion; hence the bar acts as a spring to absorb energy from vertical wheel movement and return the energy in a way that thrusts the wheel back into its original position. (Figure 1 is a diagrammatic sketch.) Therefore, in operation, as the wheel moves up and down over the irregularities it meets, the lever or support arm twists

the end of the torsion bar which, in turn, winds and unwinds. While heavy duty shock absorbers are fitted to the wheel supports and bumpers to prevent over-travel, in effect all wheels are independently sprung in a manner superior to "knee-action" on a small automobile.

At first sight this appears a rather bizarre use of the elastic property of steel. Obviously certain auxiliaries must prevent twists in the bar beyond its power for elastic recovery, but such limiting stops are necessary in any spring installation. The fact is that the torsion bar is a most effective and efficient type of spring. Thus, a manual on leaf springs issued by the Society of Automotive Engineers gives the following comparison of the effectiveness in terms of in-lb. of energy available in the various types of springs, per pound of spring weight:

Leaf springs with properly stepped leaves (the most advanced types used in passenger cars) .....	300 to 450 in-lb.
Volute spring (used in Army tanks) .....	.500 to 1000
Helical round wire spring (such as is used for knee-action suspensions) .....	700 to 1100
Torsion bar spring .....	1000 to 1500

### N.E. 9262H Steel Used

Details given in what follows represent practice developed by Spencer Mfg. Co. of Spencer, Ohio, subcontractor, and Buick Division of General Motors Corp. of Flint, Mich., as applied to the "M-18, 76-mm. Gun Motor Carriage" (unofficially dubbed the "Hellcat Tank Destroyer").

General dimensions of the spring are given in Fig. 2.

This torsion bar must be made of fine spring steel, free from excessive nonmetallic inclusions, internal flaws or other defects, as judged by deep etch tests of cross section and longitudinal sections on bars representing top and bottom of the first, middle and last ingots of a heat. Not all

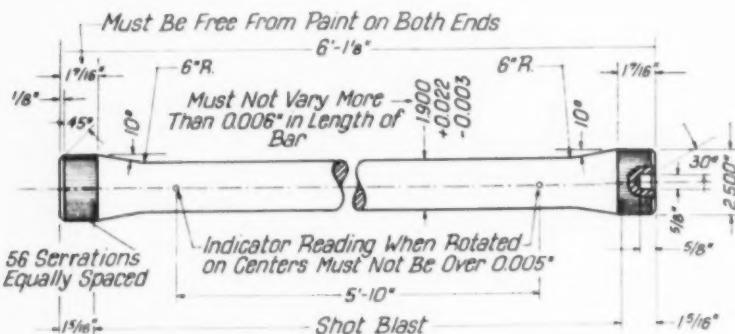
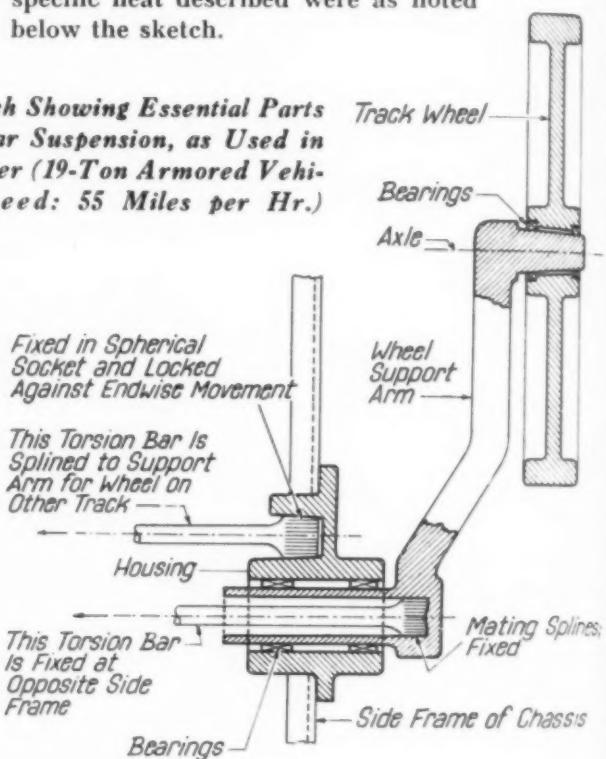


Fig. 2 — General Dimensions of Torsion Spring

steel mills are capable of producing such quality in large bars (2.15 in. dia.).

Record of an acceptance test of a representative heat from Wisconsin Steel Co. follows. Steel was basic openhearth, treated with 4 lb. per gross ton of "Grainal No. 79" (nominal composition: 20% Ti, 13% Al, 4% Zr, 0.5% B, 8% Mn, balance Fe). Analysis range and the analysis of the specific heat described were as noted below the sketch.

Fig. 1 — Sketch Showing Essential Parts of Torsion Bar Suspension, as Used in Tank Destroyer (19-Ton Armored Vehicle, Max. Speed: 55 Miles per Hr.)



ELEMENT	SPECIFIED RANGE	HEAT 58512
Carbon	0.55 to 0.65%	0.63%
Manganese	0.70 to 1.00	1.00
Phosphorus	0.040 max.	0.014
Sulphur	0.040 max.	0.021
Silicon	1.80 to 2.20	1.93
Chromium	0.25 to 0.40	0.35
Nickel	—	0.11
Molybdenum	—	0.03

Fine grain size was specified (No. 7 in this heat) and inclusions No. 2 (see 1946 Metal Progress Data Sheets No. 26 and 28, respectively).

Hardenability (J-55) was specified at 12/16 in. min. and was 17.9/16ths in this heat. The sample for hardenability test was cut 6 in. long from the original bar. It was annealed at 1600° F. for 2 hr. total time, and mica cooled. The hardenability bar was turned from the center of the original bar and heat treated according to S.A.E. standard procedure for Jominy test: Heated to 1600° F. for 1 hr.

total time, and quenched in Jominy fixture. Rockwell readings were taken on ground opposite flats, averaged, and plotted as in Fig. 3. Such tests were made on bars representing bottom of first and middle ingots and top of last ingot of each heat.

Mechanical tests were not a part of the purchase specification, but tension test bars were cut from a 7-in. length of the same bars, heat treated full size by annealing 2 hr. total time at 1600° F., mica cooled, reheated 2 hr. total time to 1600° F., quenched in S-7 oil at 80° F. for 4 min., drawn 3 hr. total time at 875° F. These tensile bars were cut so that the center of each test bar was halfway from center to outside of the original bar. Representative values were

Yield point	200,000 psi.
Ultimate strength	238,750 (T = 238.75)
Elongation	12.0%
Reduction of area	35.75% (R = 35.75)
P-Value, $\frac{T+6R}{5}$	90.65

### Manufacturing Tests for Straightness and Soundness

After cutting to length and upsetting each end, the bars were annealed for machinability 1 hr. total time at 1650° F., cooled in furnace to 1100° F., air cooled, and then cold straightened in a hydraulic press while supported on rolls to within 0.050 in. for full length as measured by dial indicators. Hardness was about 269 Brinell. Machining was then done (at least  $\frac{1}{4}$  in. on diameter being removed from the main body of the bar to get below the last decarburization or other surface defect), followed by a second cold straightening operation to 0.030 in. Lastly the entire bar between inner ends of serrations was ground to surface finish of 70 microinches or better. Each bar was then magnafluxed; it was the practice to grind to the top limit of diameter and if any surface defect was discovered, to regrind to lower limit and magnaflux the second time, hoping that the indication would be removed.

Next the bars were hardened by pushing side-wise, separated on fixtures carried on four rails, through a gas-fired, semimuffle furnace designed by Buick, and heating at 1625° F. a total of 1 hr. Quenching was in a Gogan machine, wherein the bar was clamped between eight sets of triple rollers, accurately aligned; a 3-sec. spinning in air straightened the hot bar; rotation continued throughout the 3-min. quench. (The oil used was a straw paraffin oil which conformed to 90 sec. at 100, Saybolt test; oil was maintained at 100 to 120° F. during the quench.) Tempering was done

immediately on bars in vertical position at about 900° F., 3 hr. at heat, the exact temperature depending on minor variations in hardenability. Time in the quench was also shortened somewhat in heats which proved to be susceptible to quenching cracks.

Bars were tested for straightness while hot, the limit being 0.005 in. as shown in Fig. 2. Any necessary straightening had to be done above 675° F. Final hardness limits on the splined ends were 429 to 477 Brinell. Final inspection was 100% for dimensions and 10% for surface imperfections (by magnaflux).

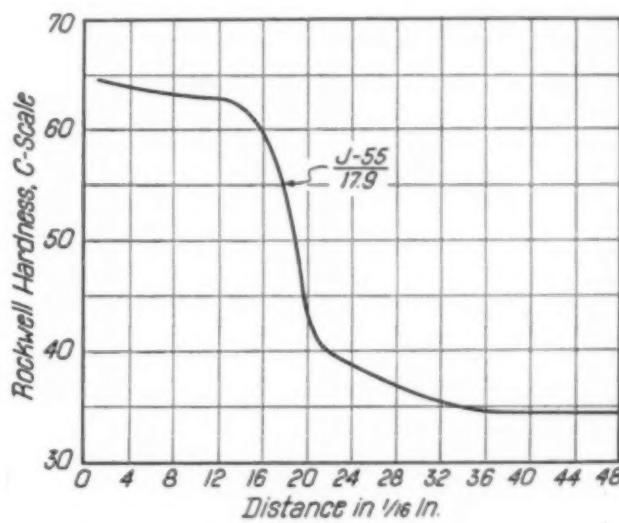


Fig. 3—Hardenability (Jominy End-Quench Test) on Representative Sample of N.E. 9262H Steel, Grainal Treated

### Surface Stresses

When this torsion bar goes into action, tension stresses as well as shearing stresses are set up in the metal, growing in intensity from center toward surface. It is well known, now, that pre-compression of the surface will raise the endurance limit of parts that carry alternating tension stresses, so it is only natural that these torsion bars should be shot-peened. However, it is worth emphasizing that heat treating is a very good way to lock up compressive stresses in the surface of steel parts, like propeller shafts (which are really torsion springs) or gears — provided the steel does not harden completely to the center so it can be quenched with a fully martensitic case over a partly fine pearlite or troostitic core. Transformation of austenite to martensite (and subsequent prompt tempering) involves a greater expansion in volume than from austenite to fine pearlite

(troostite); hence while quench cracking is possible, due to thermal shrinkage of the surface on the hot, expanded core, these thermal forces cause plastic "upsetting" of the interior which accentuates the final compressive stress in the hardened surface. (Superior endurance limits of nitrided articles are also due in great measure to the fact that formation of nitrides involves an expansion.)

The above remarks will indicate why the exact shape of the end-quench hardenability curve is of importance, and why the so-called "H steels" have been devised. It will also explain the reason why certain large users are interested in still further restricting the width of the hardenability bands in the A.I.S.I. specifications.\*

At any rate, it will be understood that the engineers responsible for the torsion bar design fully realized the necessity for correct hardening of the steel for this part, as well as the desirability of further improvement by shot-peening. In the production equipment the bars were carried sideways through the Wheelabrator cabinet, each one mounted separately on driven rollers so it would pass in and out of the shot stream in a screw-like motion at a linear rate of about 13 ft. per min. Total time for each bar was 3 min. Steel shot (Globe Steel Abrasive Co. No. P66) 0.050 to 0.060-in. diameter were used, and the thrower wheel spun at 2250 r.p.m.

The amount of surface compression resulting from such treatment is measured by exposing a flat steel strip of standard dimension to the blasting operation. The sample is held in a heavy steel block so only one surface is struck by the blast. At the end it is released from the block; the compressive stresses induced in the blasted surface by the impinging shot will cause the erstwhile flat to bow into a flat arc. Dimensions of the so-called "C-bar" are  $3 \pm 0.015$  in. long, 0.745 to 0.750 in. wide,  $0.0938 \pm 0.001$  in. thick, flatness  $\pm 0.0015$  on Almen gage No. 2, Rockwell hardness C-44 to 50. Specified are height for the torsion bar job was 0.007 to 0.008 in.

### Presetting by Twist

It is of interest to record that the torsion bar, like many highly stressed parts of aircraft engines, must be stressed beyond the normal elastic limit of the material

\*See *Metal Progress Data Sheets*, 1946 edition, No. 19 to 24.

to take advantage of its elastic properties most effectively. The basic operation is "presetting" or twisting beyond the elastic limit so the bar takes on a small permanent set. This is done in the direction of service loading, making it necessary to produce right-hand and left-hand torsion bars for installation; they were stamped with clockwise and counterclockwise arrows, and ends spotted red or yellow, respectively.

Such presetting was done in equipment like a laboratory torsion testing machine—a lathe-like machine wherein the tailstock grips one end and holds it stationary, while the headstock turns under hydraulic power. Angle of rotation was measured by an adjustable pointer and circular dial—a "troptometer". Procedure was as follows:

After the bar was mounted in the machine, it was twisted 90°, and the power released. After the return to zero load the troptometer was reset to the zero mark. The bar was then twisted 50° and the load released. If more than  $\frac{1}{4}$ " permanent set was indicated the bar was again twisted 90 to 95°, the load released, troptometer set to zero mark and another 50° twist imposed. This process was repeated at least three times, and as many more as necessary until the permanent set was less than  $\frac{1}{4}$ " after the 50° "proof" twist.

In production the measurement was simplified by using a long pointer extending from the stationary end of the bar at the tailstock to the movable pointer at the headstock end. Their divergence indicated the movement of the twisted end, measured in inches and converted to degrees.

Excessive set, after twisting, indicates subnormal physicals and is cause for rejection. A somewhat curious feature is that the presetting magnetizes the bar.

Production of the finished and accepted bars was sampled at regular times and the bar,

wheel support arm and end fixture assembly tested by imposing expected loads on the wheel axle for 80,000 cycles. Only one bar failed in these proof tests in a run of samples representing 35,000 springs. Better than the laboratory tests is the judgment of qualified ordnance officers, to the effect that the torsion bar was responsible for higher speed, reduction of shock from irregular terrain, a more stable firing platform, and a less vulnerable weapon.



## BITS AND PIECES

### Rockwell Hardness Corrections for Rounds

THE relationship between Rockwell C-scale and 30N hardness values as determined on the curved surface of steel cylinders and the "true" hardness as measured on flats has been previously recorded in technical literature. See, for example, Fleischmann & Jenkins in *Metal Progress* for February 1945, p. 275, and Wallace in *Materials and Methods* for February 1946, p. 471.

Similar relationships for Rockwell A-scale and 45N hardness readings were needed for use at Pratt & Whitney Aircraft Division; a program was therefore carried out to establish these relationships as well as to verify the previously reported values. Rockwell hardnesses were measured on curved surfaces of steel cylinders up to 1 in. diameter, and corresponding "true" hardness was determined on flats. The resulting relationships are presented in four nomographs reproduced in the data sheet, page 776-B.

S.A.E. 6150 steel specimens of eleven different diameters ranging from 0.1 to 1.0 in. were heat treated to give hardness increments of about 5 Rockwell C units within the range of C-20 to 65. In hardness measurements on cylindrical surfaces, the "Cylindron-Jr." anvil was used for specimens over 0.25 in. diameter, and the V-notch block for specimens smaller than that diameter. The point anvil or the 3-in. table was used for measurements on the flat. Four or more readings were taken at each observation, depending on the consistency of readings.

The nomographs were constructed from curves plotting the hardness on flats versus the hardness on cylindrical surfaces for each of the eleven diameters. The data for the Rockwell C-scale and 30N-scale are substantially in agreement with results determined by the previous investigators noted above.

To determine the correction factor, a straight-edge is laid across the appropriate nomograph, intersecting the two vertical axes at the diameter of the cylinder and the Rockwell hardness measured on the cylindrical surface. The correction factor is read from the point of intersection of the straightedge and the diagonal axis.

Nomographs should be used *only* in the ranges indicated on the axes. (G. E. POOLE and J. HUNT, materials development laboratory, Pratt & Whitney Aircraft Div., United Aircraft Corp.)

### Stabilizing Aluminum Castings

IT is well known that dimensional stability of quenched high-alloy steel parts—dies, gages, precision forming tools—is improved by treating them at subzero temperatures. The reason is also amply proved and well known: Residual austenite, retained in such steels at atmospheric temperatures and tending to transform with age and slight temperature fluctuations, is almost completely transformed to martensite during the cooling to  $-150^{\circ}$  F. Subsequent warming followed by adequate tempering will relieve internal stresses, stabilize the martensite, and avoid subsequent changes in volume during use.

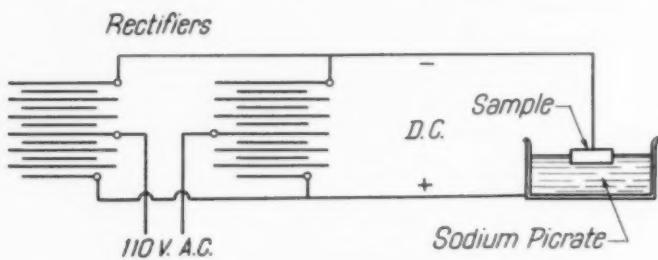
It is not so well known that similar results accrue to aluminum alloy castings. Nor is the reason so well established, although the hardening process in both steel and aluminum involve the same class of physical-chemical changes in supersaturated solid solutions.

At any rate, cold treating solved a difficult production problem in the manufacture of hydraulic valves for aircraft. Prior to its adoption, it was common to have valves tear while being drilled and tapped. Distortion was excessive as a result of general machining operations. A Koldhold industrial chilling unit was used to subject a few

of these valves to temperatures of  $-150^{\circ}$  F., with outstanding results. Cold treated valves can be drilled and tapped without tearing; original dimensions are consistently held after machining. The manufacturing routine now requires that these valves be cold treated before doing any work on them. As a consequence valve production has been greatly increased, quality improved and production costs considerably lowered. (AVERY C. JONES, field engineer, Bowser, Inc.)

## Economical Direct Current Source for Electrolytic Etching

THE PRACTICE of using lead storage batteries or dry cells for etching McQuaid-Ehn grain size samples or sections containing excess carbides by electrolytic sodium picrate has been discontinued due mainly to inconveniences in maintaining power at full strength. The present direct current supply was obtained by using 110 volt,



alternating current supply (60 cycle) and rectifying it by two selenium, selenium oxide rectifiers, the resulting direct current source being approximately 90 volts with no load, which drops to 5 volts when etching samples.

Excellent results are obtained with this etch in 3 to 5 sec., depending upon size of sample etched. Much to our relief the charging or changing of batteries has been eliminated by a constant source of direct current. All we need now is simply to throw a switch. The circuit diagram is sketched herewith. (J. G. CUTTON, metallurgist, Youngstown district, Carnegie-Illinois Steel Corp.)

## Handling Large Gears in Production

MECHANICAL handling of small parts through the heat treating department in mass production is an old, old story, but too often an observer suspects that the principles are forgotten when the weight of the individual part becomes too heavy for manual operations. Some brief remarks, therefore, on how we handle large gear blanks may be useful.

An example may be the blank used for locomotive gearing; it may be 27 in. dia. with a 6-in. face — a steel ring or a wheel rolled on a tire or a wheel mill. Blanks are delivered in car lots and stored in the stock yard on edge, lined up so a power truck with elevator fork can pick up four to six at a time. Jib cranes are used at the various machine tools. Overhead cranes transfer the gear blanks along the aisles, six or so each trip, by simply inserting a short steel shaft through the hubs and looping the chain sling over either end. From aisle to aisle, transfer cars pushed by power truck are convenient.

In the heat treating department gears are picked up one at a time by a triad of special hooks slung from an electric hoist on a jib crane and placed flat on the furnace floor rails. Quenching (in the horizontal position) is done with the same equipment. (O. P. ADAMS, gearing division, Westinghouse Electric Corp.)

## Preparing Bearing Shells for Babbetting

YEARS AGO, when the predominant numbers of large babbitted bearing shells were made of cast iron, a series of axial and circumferential dovetailed slots would be cut into the bore of the shells. Babbitt will not bond readily to cast iron and therefore the intent of the slots was to assure good anchorage.

In the transition from the use of cast iron to steel and bronze shells which would bond to babbitt, these slots were eliminated in the smaller sized bearings. The larger bearings however, regardless of material, still carried them as an additional safeguard against the chance of having a loose babbitt lining.

The importance of saving man and machine hours plus the critical shortage of tin has caused us to replace the slots with a serrated bore. A 12-pitch serration was decided upon, which gives approximately 50% more surface per linear inch than a smooth bore. The saving in babbitt that formerly filled these slots is considerable, and the saving in man and machine hours is indeed welcome. The slotter operation to cut the axial dovetails was eliminated and the entire bore is finished on the lathe or boring mill on one setup.

This serrated bore is now used in Westinghouse shops in all babbitted bearings except those made with backings of cast iron and aluminum bronze, two alloys which will not bond to babbitt without special salt bath treatments or electroplating. (A. A. GOODMAN, steam division, South Philadelphia works, Westinghouse Electric Corp.)



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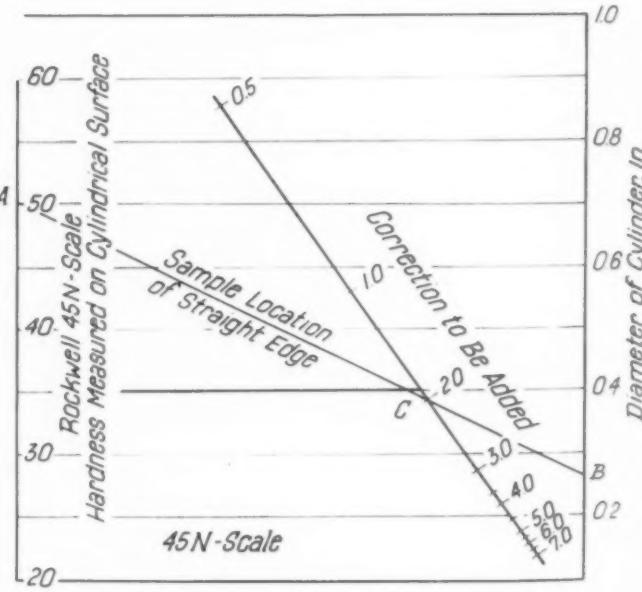
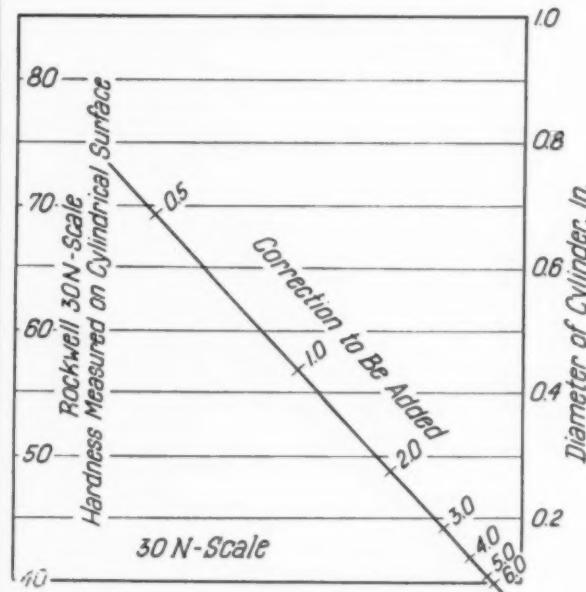
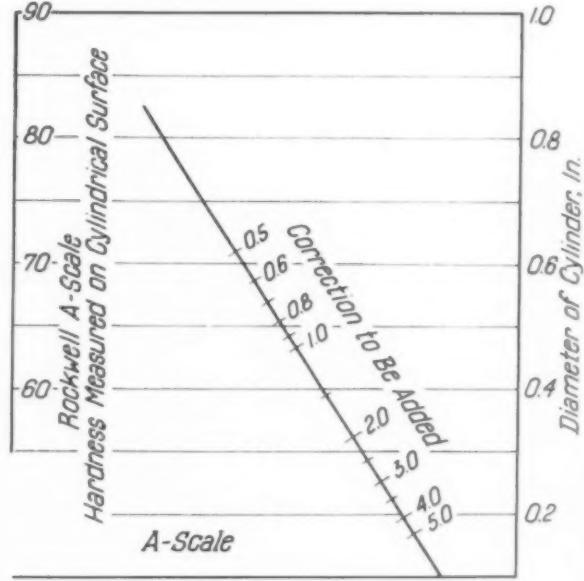
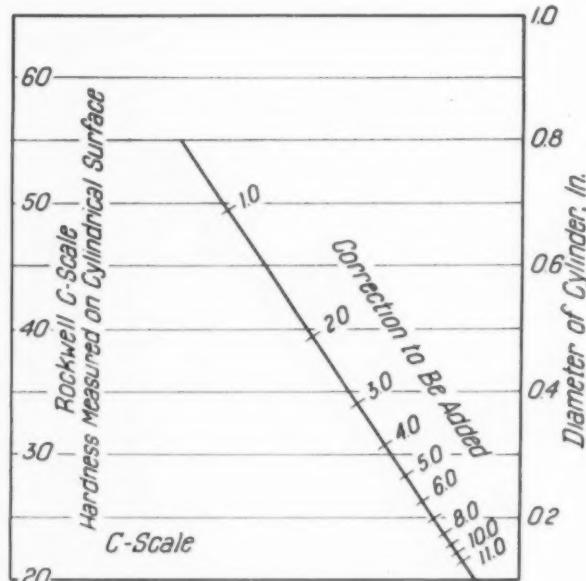
May, 1947; Page 776-A

## Hardness Corrections for Rounds

By G. E. Poole and J. Hunt, Pratt & Whitney Aircraft

NOMOGRAPHS for corrections to be added to Rockwell hardness readings taken on cylindrical surfaces of steel rounds to correct them to hardness of same specimen if measured on carefully ground flat of adequate width. Method of use is shown on lower right nomograph. A steel round 0.260 in. diameter was tested, using

the 45N-Scale, which read 50. Between 0.260 in. diameter (point B) and 45N-50 observed hardness (point A) draw a line or lay a straight-edge. Its intersection on the diagonal line (point C) reads 2.0, the plus correction. Hardness if measured on a flat would then have been  $50 + 2.0 = 52$  on the 45N-Scale.



## MICROSTRUCTURES AND STRUCTURAL DIAGRAMS FOR Fe-Ni-Cr ALLOYS

By ANTON deS. BRASUNAS and JAMES T. GOW  
Research Engineer and Assistant Supervisor, Battelle Memorial Institute

THE SERIES of photomicrographs on the following two pages and the ternary diagrams reproduced later as Fig. 1 and 2 are from the Alloy Casting Institute's research program conducted (now for some years) at Battelle Memorial Institute in Columbus, Ohio.

The microstructures of Fe-Ni-Cr alloys containing 0.4% carbon, 1.2% silicon and 0.8% manganese, as influenced by variations in chromium from 11 to 31% at 5% intervals, and variations in nickel from 0 to approximately 68% at about 4% intervals, are shown in the assemblage on the two facing pages, overleaf. These microstructures are of cast alloys heated to 1800° F. for 100 hr., then furnace cooled, etched in aqua regia (1 part nitric acid to 4 parts hydrochloric acid), and magnified 200 diameters. The microstructures of these and other alloys, supplemented by magnetic permeability data, were used to construct the structural diagrams of Fig. 1 and 2.

The composition boundary for wholly stable austenitic alloys was shown by earlier extensive studies of the "HH type alloy" (containing 23 to 27% Cr and 10 to 13% Ni) to be defined, for practical considerations, by the equation

$$\text{Cr} - (16 \text{ C}) = 1.7 \text{ Ni}$$

This was devised by J. T. Gow and O. E. Harder in a paper entitled "Balancing the Composition of Cast 25% Chromium, 12% Nickel Type Alloys"

in *Transactions A.S.T.M.*, V. 30, Dec. 1942, p. 855, and called the "ratio factor". When a line corresponding to this Ni:Cr ratio is drawn on the ternary diagram, alloys whose nickel content is slightly less than the amount called for in the equation and which therefore fall immediately to the left and above this boundary line consist of an essentially stable austenite plus a little ferrite, with or without some of the sigma phase, depending upon the exposure temperature or cooling rate. Alloys of a composition in which the nickel is greater than the amount called for in the equation and which therefore fall to the right and below the C-shaped boundary curve on the ternary diagram will be fully austenitic.

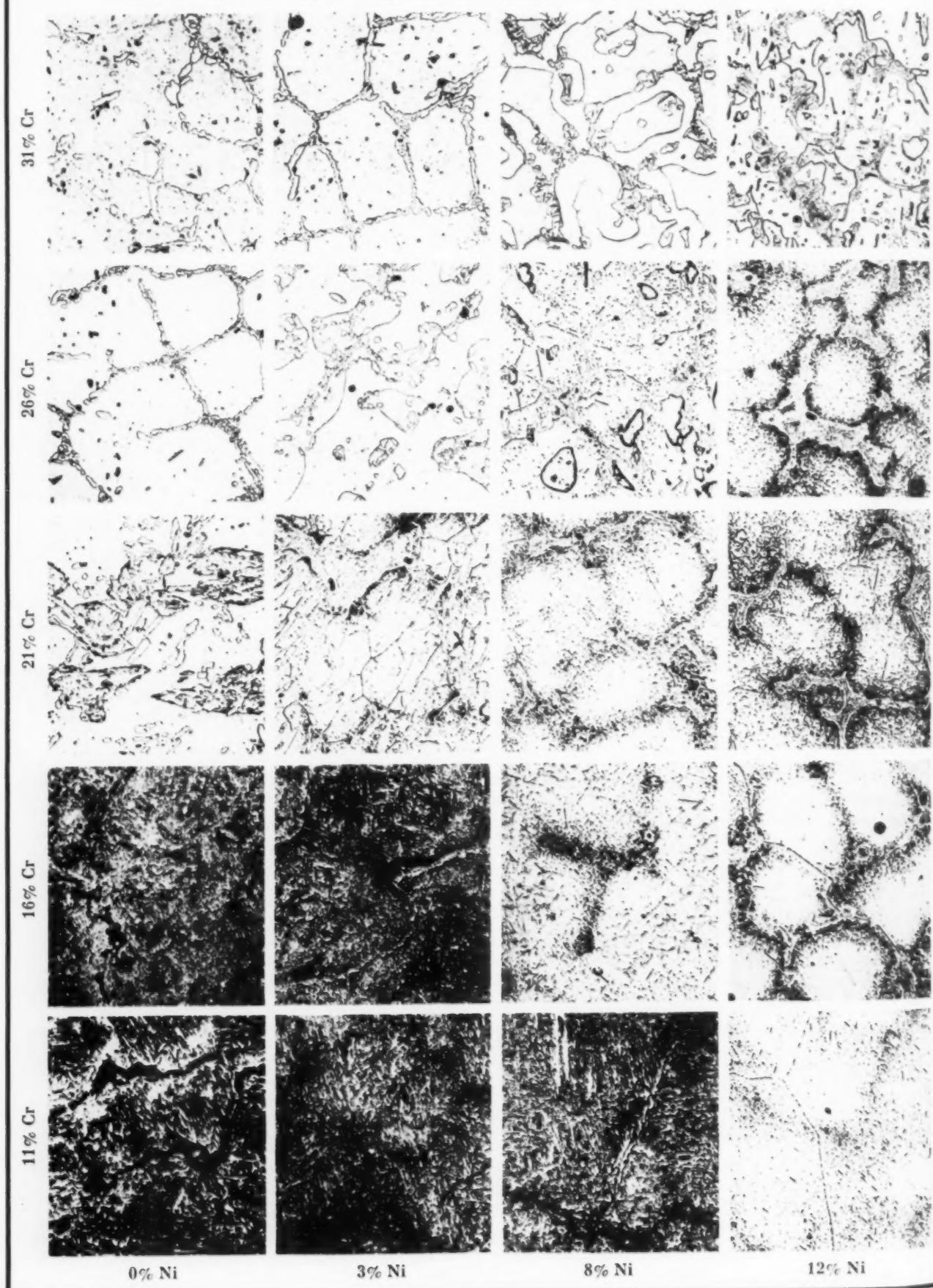
In contrast to this temperature-structural relationship, for the 23 to 27% chromium alloys, is the more complex relationship occurring for compositions containing less than about 22% chromium. For these lower chromium alloys, the composition boundary for alloys with wholly austenitic microstructure is shifted considerably with the temperature of exposure (during long annealing or use). The magnitude of this boundary shift increases as the chromium content is lowered to 11%, which is the lower limit studied.

The austenite boundaries under four conditions of heat treatment, for alloys containing from 11 to 28% chromium, are shown in Fig. 2.

# Microstructures of Cast Fe-Ni-Cr Alloys

200 $\times$ . Annealed 100 hr. at 1800° F. Alloys also contain 0.4% C, 1.2% Si, 0.8% Mn

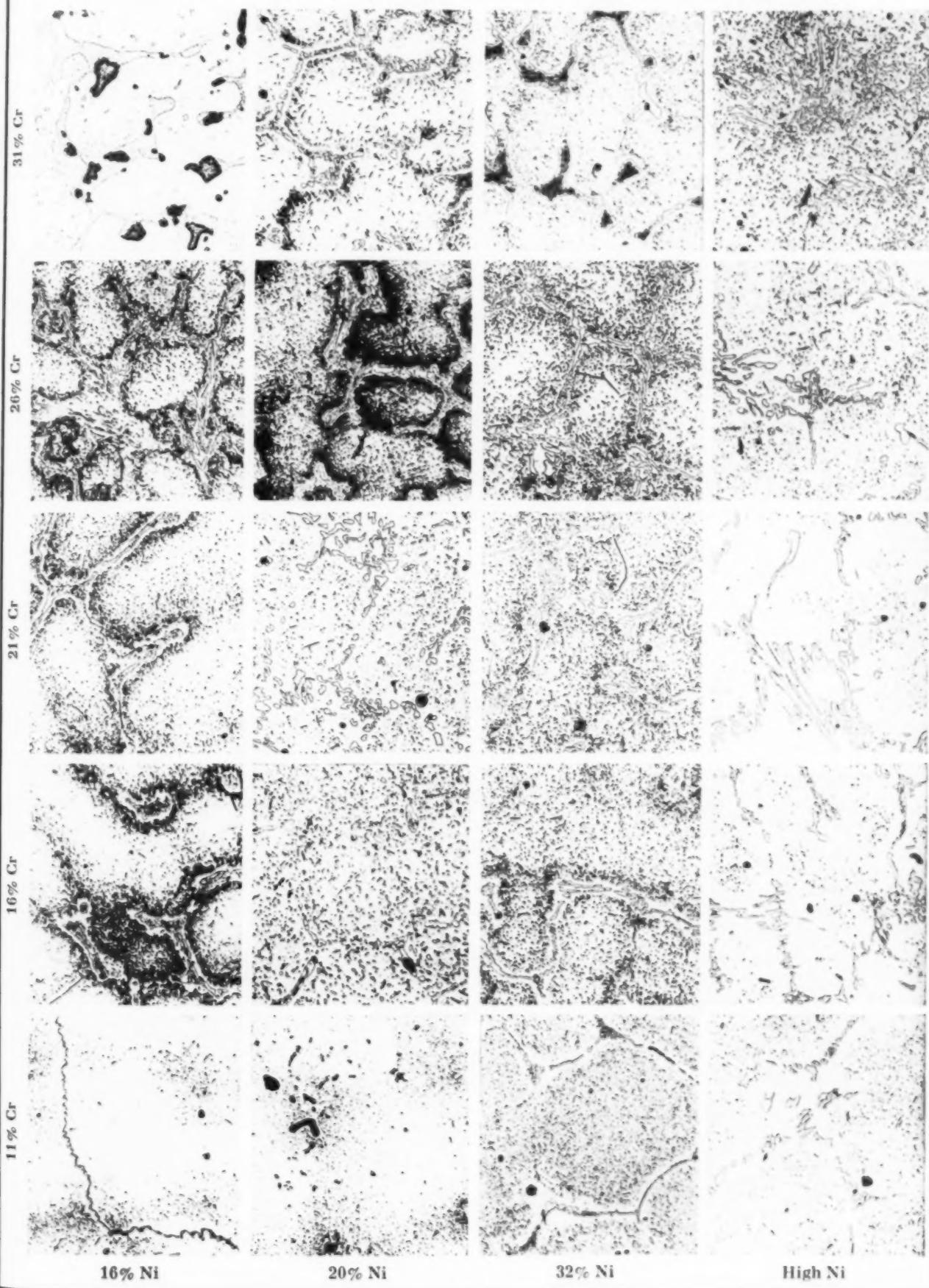
Contribution from Alloy Casting Institute's Research at Battelle Memorial Institute



# Microstructures of Cast Fe-Ni-Cr Alloys

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Contribution from Alloy Casting Institute's Research at Battelle Memorial Institute



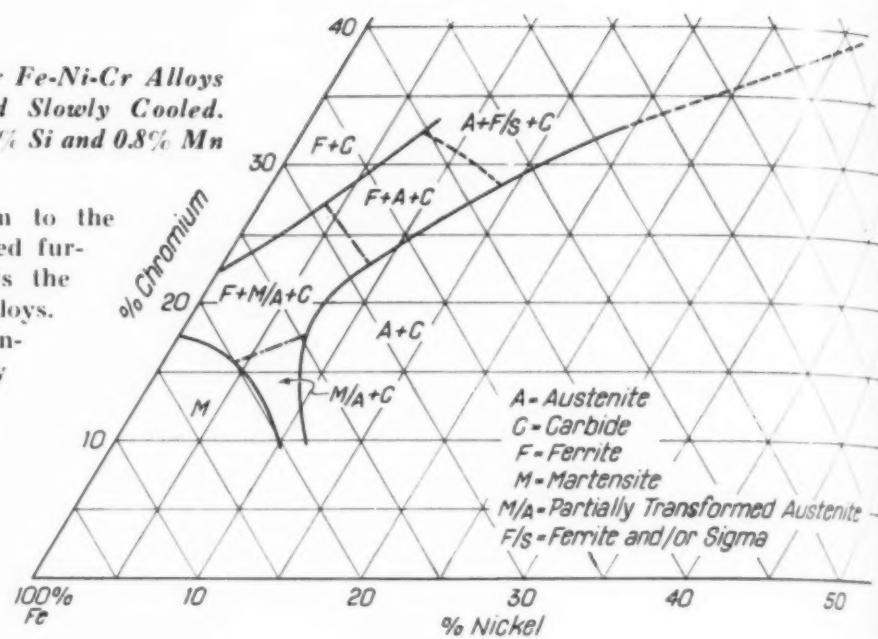
**Fig. 1—Structural Diagram for Fe-Ni-Cr Alloys Aged 100 Hr. at 1800° F. and Slowly Cooled.** Alloys contain about 0.4% C, 1.2% Si and 0.8% Mn

The region on the diagram to the right of the boundary line located furthest to the right (line *def*) is the region of the stable austenitic alloys.

The shaded region *cdec* contains alloys which are normally austenitic for most conditions of heat treatment, but which will transform somewhat by mechanical work or by mechanical work followed by heating at moderate temperatures. This is termed the composition region of "marginal austenitic" alloys. Alloys within this region were studied in work directed to developing alloys low in chromium and nickel for service up to 1400° F.\* It is largely on the basis of observations made at that time that the region *cdec* is placed on the present diagram, Fig. 2.

Region *aecba* contains alloys which are austenitic at certain elevated temperature ranges and which will remain austenitic at room temperature if cooling is rapid enough from the austenitizing temperatures. However, slower cooling conditions, mechanical work, or a reheat at moderate temper-

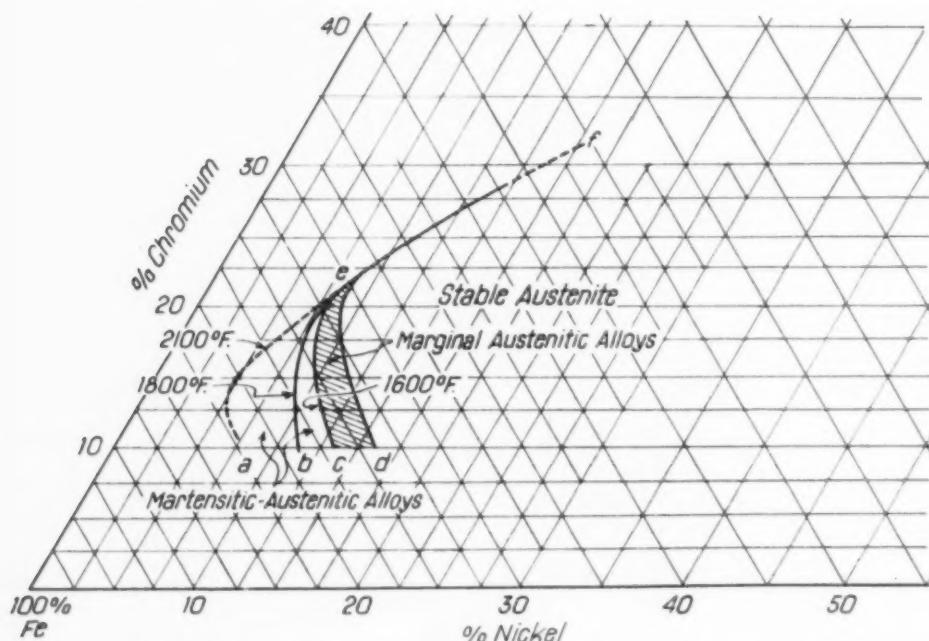
\*O. E. Harder and J. T. Gow, "An Emergency Heat Resistant Alloy", *Transactions* **9**, V. 32, 1944, p. 408.



ature will transform the austenite, generally to martensite. The alloys of this region are termed "martensitic-austenitic" alloys because they can be heat treated to consist wholly of either structural constituent or to have a combination of both structures present.

From the standpoint of structural stability, the alloys of merit for heat resistant applications are to the right of the boundary line *def*. The great differences that may occur in the properties of alloys in the vicinity of this boundary — having relatively small differences in composition but sufficient to change the alloy from a wholly austenitic structure to one with some ferrite — have been demonstrated by the earlier studies of the 25% chromium, 12% nickel (HH) type compositions.

This realm of alloy compositions is being tested for high temperature corrosion resistance in several types of atmospheres, and some of the data have been presented in Alloy Casting Institute's Bulletin No. 4 (March 1945), and in *Proceedings of the A.S.T.M.* V. 46, 1946, by A. deS. Brasunas, J. T. Gow and O. E. Harder, as a paper entitled "Resistance of Iron-Nickel-Chromium Alloys to Corrosion in Air at 1600 to 2200° F.".



**Fig. 2—Boundaries of Fully Austenitic Alloys for Various Treatments:**

Some years ago the Boston Chapter established the "Sauveur Memorial Lecture", an annual event of the Chapter's winter season. In January of this year,

Morris Cohen was the lecturer, and during his discourse brought together in orderly array the results of his students' investigations on the tempering process.\*

Tempering of toolsteel is a complicated interplay of at least four different processes, and when properly done, yields tools of improved cutting ability.

## TEMPERING OF TOOLSTEELS (Part I)

By MORRIS COHEN

Professor of Physical Metallurgy, Mass. Institute of Technology, Cambridge

TEMPERING is a heating operation carried out below the critical temperature and applied to hardened steel in order to obtain a more satisfactory set of properties than can be secured by quench hardening alone. In other words, the tempering process starts with the steel piece in the hardened condition. Permit me, then, to review very briefly the fundamentals of the hardening operation.

Figure 1 presents the transformation curves for a complex tool material (specifically 18-4-1 high speed steel). If the steel is cooled from its usual austenitizing temperature of 2350° F., the austenite may transform to carbide and pearlite in the range of 1400 to 1200° F., the lower part of the C-curves indicating how far the transformation proceeds as a function of holding time in this temperature range. (The transformation product is called "spheroidite" if the carbide is in rounded form.) However, if the cooling rate is too rapid for the austenite to transform in this range—that is, if the steel is cooled past 1400° F. in 5 or 6 min.—the transformation may occur partially in the range of 700 to 400° F., if it is held there long enough. Here the decomposition product is known as "bainite", and although bainite is considerably harder than pearlite or spheroidite, it is also easily avoided in the usual hardening operation. The diagram, for example, shows that the

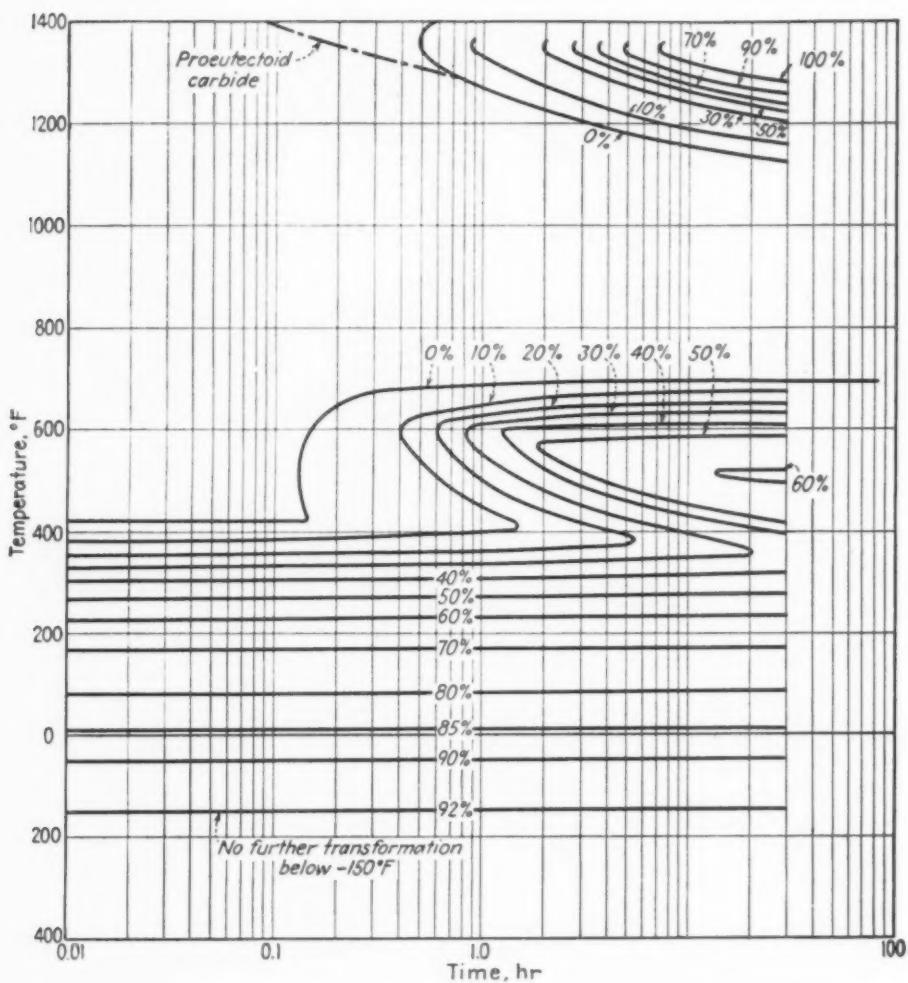
steel would have to stay at 600° F. for 8 min. before the first bainite appears, and 24 min. before 10% of the austenite changes to bainite.

The *true* hardening of toolsteel takes place below 450° F., for this is where the austenite transformation product is martensite. Martensite starts to form in this 18-4-1 steel at the temperature corresponding to the top horizontal line, which is now called the M point (or more particularly the Ms temperature, where "M" stands for martensite and "s" stands for "start"). The reaction of austenite → martensite continues on cooling, 10% being formed by the time the temperature reaches the second line, 20% at the third line, 30% at the fourth, and so on. At room temperature, in this 18-4-1 steel, the microstructure contains 80% martensite, leaving 20% retained austenite. Cooling below room temperature converts all but 8% of the austenite into martensite.

It is important to note that martensite forms characteristically *on cooling*, the rate of cooling being of minor importance. Fast cooling does not avoid this transformation, because a curve representing falling temperature cuts through the horizontal lines no matter how rapid the quench. By the same token, slow cooling through this range also yields martensite.

These kinetics of hardening apply to all toolsteels. The pearlite and bainite ranges may overlap to produce a single "nose" on the transformation diagram, as they do in plain carbon steel; the martensite range may vary from steel to steel as a function of chemistry; but the essence of hardening remains the same: Cooling must be fast

\*The text printed here (and in a sequel next month) is substantially complete, with the exception of the introductory tribute to the late Albert Sauveur and a prologue containing a brief consideration of the process of quench hardening.



**Fig. 1 — Transformation Curves for 18-4-1 High Speed Steel. Austenitizing temperature, 2350° F. (Gordon)**

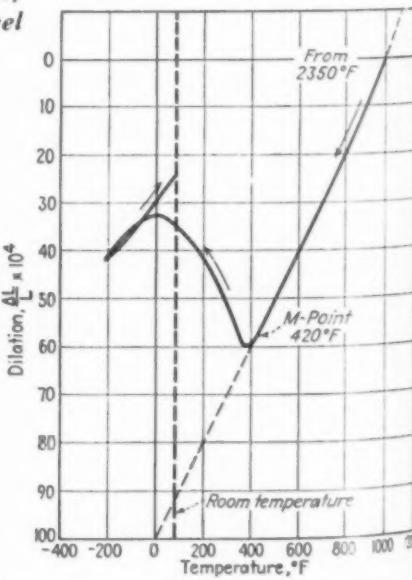
enough to suppress the austenite transformation into soft products at temperatures above the M point; if this is accomplished the austenite will then transform to martensite on cooling below the M point, where the cooling rate is not a critical factor.

#### *Hardened Steel — Enter Tempering*

Now what does this mean to the tempering operation? Figure 2 shows how the length (or volume, if you will) changes during the hardening quench. Again, 18-4-1 is used for purposes of illustration. The steel contracts normally (almost proportionally with temperature) until the hardening reaction sets in at the M point (420° F.). As the martensite continues to form on cooling, there is a marked expansion because this product is more voluminous than the austenite from which it forms. The martensite itself is very hard and strong, but is so brittle that it ruptures readily under impact. It also tends to contract on aging at room temperature, and therefore is dimensionally unstable.

Expansion accompanying hardening does not proceed uni-

**Fig. 2 — Dimensional Changes During the Hardening and Subcooling of 18-4-1 High Speed Steel**



formly throughout the steel due to the fact that the temperature varies from point to point in the cooling process. Tiny regions of the steel expand at different rates at different times and exert pressure on one another. As a result high internal stresses are generated and remain "locked up" because the steel has very little plasticity near room temperature. These stresses are harmful to the as-hardened steel, in that they may lead to premature failure or may cause dimensional changes after finish-grinding to size.

Another constituent of the hardened steel is the retained austenite, which remains from the hardening reaction. If the cooling is continued through and below room temperature, the austenite → martensite reaction progresses in a normal fashion, as indicated in Fig. 1, but when the cooling is stopped at room temperature, as in an ordinary hardening quench, the transformation is interrupted. In 18-4-1 toolsteel, about 20% austenite remains at room temperature. In plain carbon toolsteels, the amount

of retained austenite runs from 3 to 12%, and this is also true for the low-alloy toolsteels (such as manganese oil hardening toolsteel, chromium ball bearing steel, and tungsten nondeforming toolsteels). In high chromium steel (12% Cr, 1.5% C) which air hardens, we find 20 to 25% retained austenite at room temperature and in 1% carbon, 5% chromium as much as 30 to 35%.

Figure 3 shows the important fact that the amount of retained austenite depends upon the hardening temperature; the more carbide that is dissolved, the lower is the M point and the more austenite remains untransformed on reaching room temperature.

Austenite is thought of as ductile and tough, yet *retained* austenite does not seem to help

These, then, are the internal factors in hardened toolsteel that require alteration by the tempering operation:

1. The toughening and the stabilization of the martensite.
2. Relief of internal stresses.
3. Removal or stabilization of the retained austenite.

(Excess carbides, which are not dissolved in the austenitizing treatment, go through the tempering unaffected; they play no role in the tempering process.)

All this must be accomplished without lowering the hardness to the point where tools would be too soft for intended use. In other words, tempering must provide a balanced combination of hardness, toughness and dimensional stability.

### *Stages of Tempering — Via the Microscope*

Structurally speaking, there are four main stages that occur during the tempering of steel:

1. Decomposition of the martensite into an aggregate of ferrite and a transition precipitate.
2. Transformation of the retained austenite.
3. Formation of cementite (iron carbide) from the aggregates of the first two stages.
4. Conversion of the cementite into more stable alloy carbides, when strong carbide-forming elements are present.

Of course, not all these stages take place in the commercial tempering of toolsteels because the hardness cannot be allowed to drop much below the as-quenched level, and therefore the tempering temperature and the time at temperature must be restricted.

Let us first consider these tempering changes in terms of microstructure. We shall use a 1% carbon steel for this purpose, but alloy it with approximately 5% nickel in order to increase the amount of retained austenite. (This is not a commercial toolsteel, but it serves nicely for illustrating the changes that go on.) Figure 4 shows microstructure of this steel after hardening in oil at 70° F. (quenching after 30 min. at 1700° F.), and also after this steel has been tempered 5 min. at the indicated temperatures.

At 250 to 400° F. we see the first stage of tempering. It consists of a progressive darkening of the martensite. As will be explained later, this is caused by a precipitation in the martensite

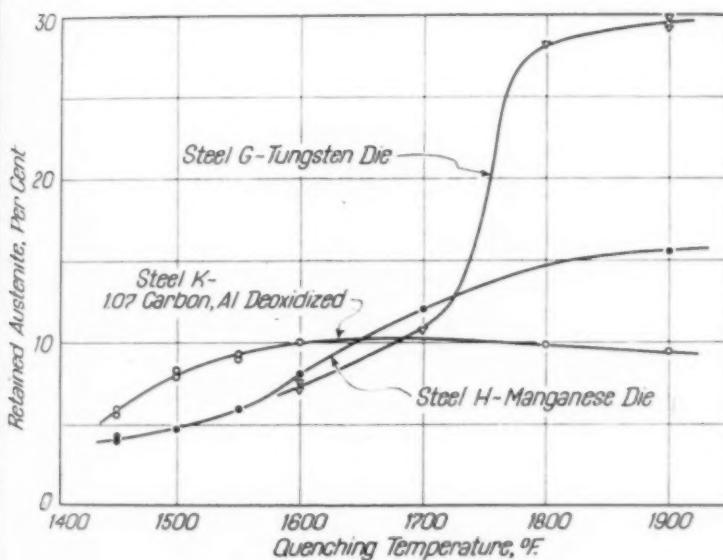


Fig. 3 — Effect of Austenitizing Temperature on the Amount of Retained Austenite in Three Toolsteels After Quenching to 80° F. (Fletcher)

hardened toolsteels in these respects. I venture to suggest that the reason for this anomaly lies in the instability of the austenite. For supporting evidence, it is known that austenite may embrittle hardened steel if it transforms under the strains of service. Furthermore, some grinding checks are undoubtedly caused by the volume changes resulting from localized austenite transformation under the pressure of the grinding wheel. We now have definite evidence that retained austenite transforms *slightly* upon aging at room temperature, even without external stimulation. This is another factor in dimensional instability, for if only 0.75% of the steel's volume transforms at room temperature, an expansion of 0.0001 in. per in. occurs, which is enough to give trouble for many precision parts.

which makes it (among other things) etch more rapidly. The numerous patches of white background in the tempered samples are retained austenite, which does not change during this first stage of tempering.

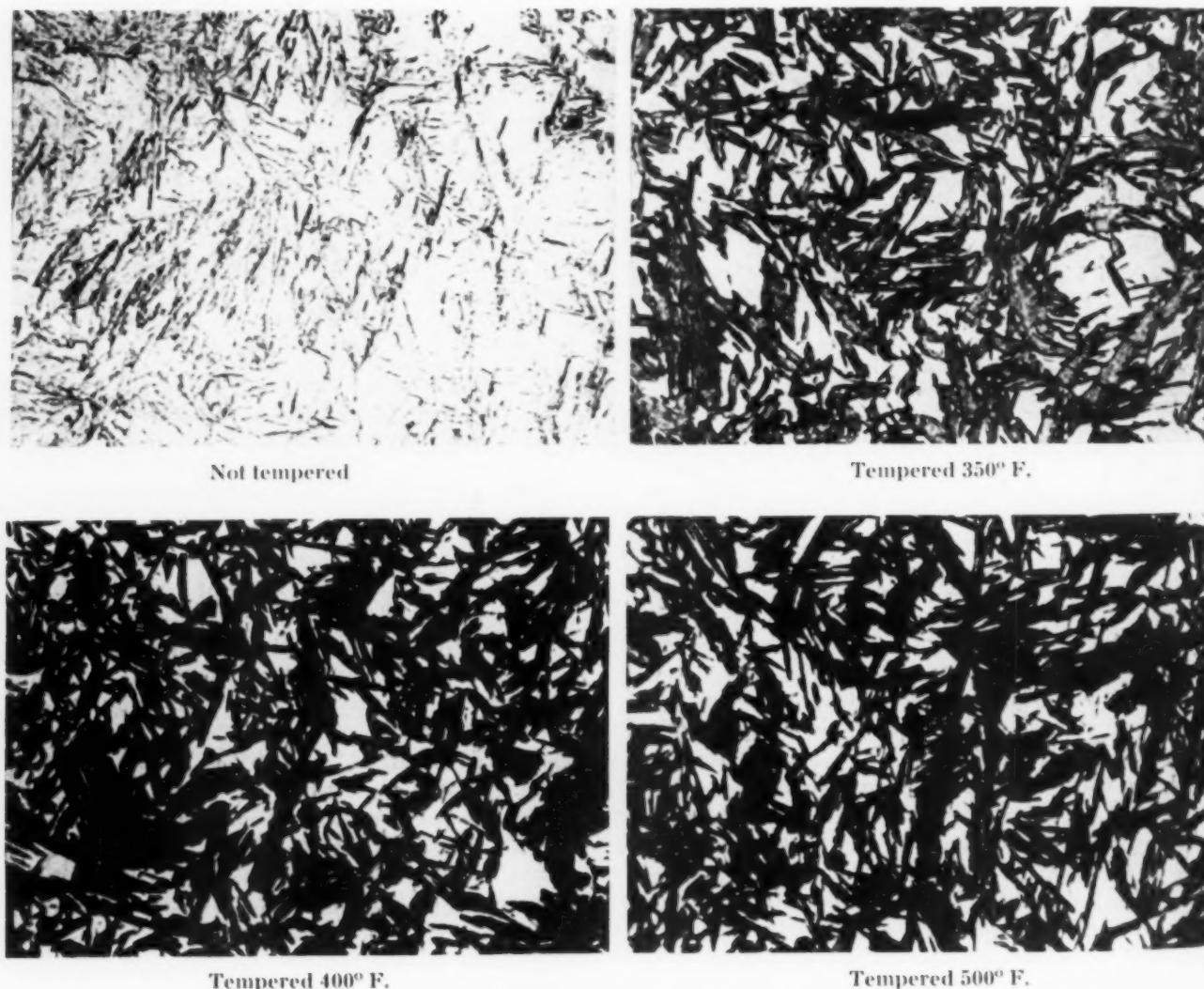
The second stage of tempering is illustrated by the specimens tempered at 500, 600 and 650° F. Note how the white austenite areas disappear gradually as the temperature is raised. The product (when very lightly etched) looks very much like bainite, such as would form isothermally out of primary austenite after quenching into a hot bath within this temperature range. We shall show later that this secondary product is, in fact, bainite.

At about 650° F., the third stage of tempering sets in. The cementite particles emerge out of the previous dark-etching structure and develop progressively at 700 to 1000° F.

If we raise the temperature still further, the structure ultimately becomes completely spheroidized and, if this were an alloy steel containing strong carbide-forming elements, there would be a gradual change-over of the cementite to the more stable alloy carbide. This fourth stage of tempering is not easily detected under the microscope because all the carbides are light etching. Furthermore, this stage is not usually encountered in commercial work.

#### *Stages of Tempering — Via the X-Ray*

Now let us go back and examine these stages a little more critically. The crystalline structure of martensite is body-centered tetragonal, which means that the unit cell has an arrangement of atoms as shown in Fig. 5. The open circles represent iron atoms and they lie at the corners of a



*Fig. 4 — Microstructures of 1% C, 5% Ni Steel, Oil Quenched From 1700° F. and Tempered 5 Min. at Temperatures Shown. Etched with nital; 1000 $\times$ . (Antia and Fletcher)*

rectangular prism with a square base. That is, the distance  $AB=AC$ , but this does not equal the height  $AD$ . (If  $AD$  were equal to the edge dimension of the base, we would have a regular cubic structure, with the atom  $E$  in the center, making the structure body-centered cubic, and identical with ordinary ferrite.) Alloying atoms like nickel, chromium or tungsten simply substitute for the iron atoms at occasional points in the lattice.

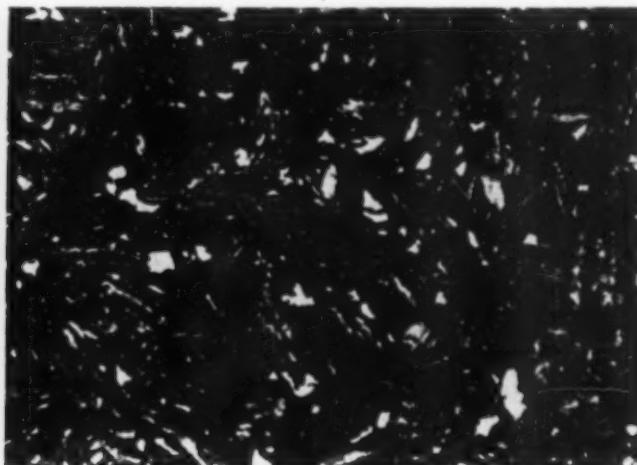
The reason that this structure is not cubic is due to the presence of carbon atoms (represented as solid circles) which are too "large" for the spaces they occupy in the lattice and which stretch the cube in one direction, thus forming the tetragonal structure. Actually in commercial steels nowhere near all of these black positions are occupied — only about 1 in 20 of these possible positions is filled in a 1% carbon martensite. But this is still enough to produce a tetragonal structure detectable by X-rays; in fact, the axial ratio  $AD:AB$  (usually written  $c/a$ ) is a direct measure of

the carbon content of the martensite. The fewer the black positions occupied by carbon, the closer the height dimension approaches the base dimension, and the closer the structure approaches the cubic form of ordinary ferrite.

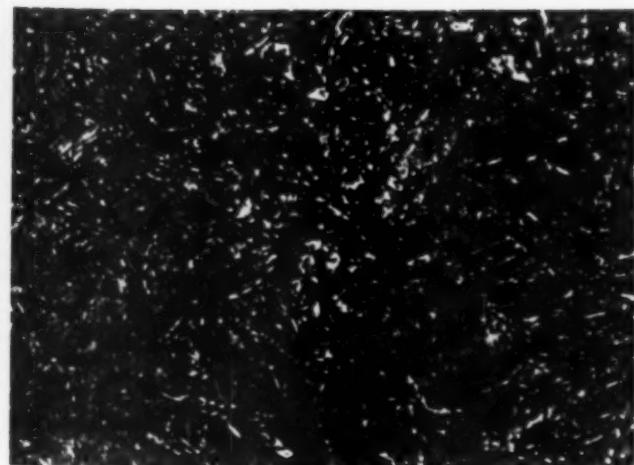
With this brief excursion into crystalline architecture as a background, we are now in a position to consider the results of an X-ray study made on the very samples whose microstructures were just described. In Fig. 6 are plotted the X-ray changes versus the tempering temperatures. During the first stage of tempering (up to 400° F. in this steel) and coinciding with the darkening of the martensite plates under the microscope, we find that the lattice dimensions of the martensite are changing, the height  $c$  of the unit cell undergoing a marked decrease and the base dimension  $a$  undergoing a slight increase. The axial ratio  $c/a$ , which we have said is a measure of the amount of carbon dissolved in the martensite, approaches unity during this stage of tempering,



Tempered 600° F.



Tempered 650° F.



Tempered 700° F.



Tempered 1000° F.

**Fig. 5 — Body-Centered Tetragonal Structure of Martensite (Petch)**

and the tetragonal martensite becomes cubic ferrite.

This means that the carbon atoms move out of the martensite crystal ("precipitate"). As a first guess, one might expect the precipitate to be cementite, the well-known iron carbide, but this does not turn out to be true. We shall see that cementite does not actually form until the third stage, above 650° F. The early precipitate is called a "transition" or "intermediate" precipitate; lacking more precise knowledge it is thought of as simply a preliminary step in the mechanics of forming crystals of cementite.

Such transition precipitates are now well recognized in age-hardening alloys.

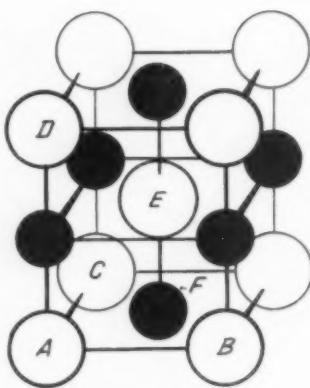
Figure 6 shows that the amount of retained austenite remains practically unchanged at 48% in this steel during the first stage of tempering, but during the second stage (400 to 650° F.) there is a progressive decrease in its quantity. Its transformation can be followed quantitatively by the diminishing intensities of the austenite lines in the X-ray diffraction spectrum. The attendant constancy of the austenite lattice parameter indicates that no detectable change in its chemistry occurs during the transformation.

Still later, in the third stage (650° F. and up, for this steel), cementite lines begin to appear in the X-ray pattern, becoming more numerous and more intense as the tempering temperature is raised. However, it should be kept in mind that cementite may actually form long before these lines can be found in the X-ray spectrum.

The fourth stage, conversion of the cementite into a more stable alloy carbide, does not come into this picture because the nickel steel under consideration does not form a stable alloy carbide; the nickel remains in solid solution in the ferrite, replacing an iron atom here and there in the body-centered cubic lattice.

### Stages of Tempering — Via the Magneto-Dilatometer

In all the observations described so far, the samples were tempered and returned to room temperature for the measurements. One might well wonder whether these changes actually occur at the tempering temperature, or during the cooling therefrom. This question can be readily

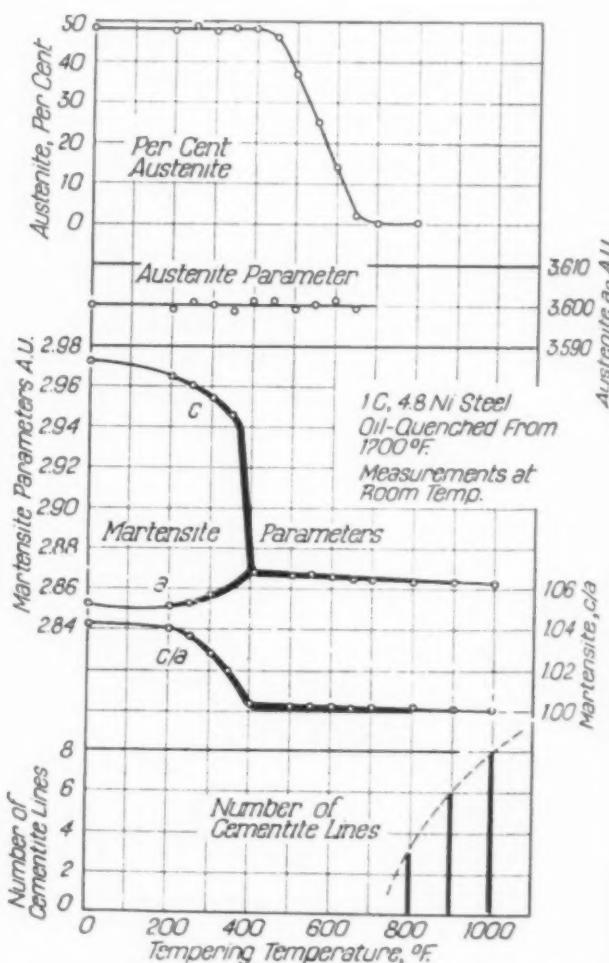


answered by making observations at temperature.

Figure 7 provides such information in the form of magnetic and length changes during reheating of a hardened carbon toolsteel in a combined magnetometer and dilatometer. As is proved by a well-known experiment in elementary physics, when a substance is heated, it normally expands almost proportionally with the temperature; if the material is ferromagnetic, its intensity of magnetization in a given field-strength normally

decreases. However, when hardened steel is heated, the tempering effects are superimposed on the normal temperature changes.

As far as volume is concerned, there is a superimposed contraction in the first stage (martensite → ferrite + transition precipitate), a superimposed expansion in the second (austenite



**Fig. 6 — X-Ray Measurements Made on Tempered 1% Carbon, 5% Nickel Steel. Same specimens as photographed in Fig. 4. (Antia and Fletcher)**

→ bainite), and a superimposed contraction in the third (transition precipitate → cementite). The second stage expansion is barely perceptible in the dilation curve of Fig. 7 because there is so little retained austenite in this plain carbon steel, as-quenched. However, the magnetic measurements are much more sensitive and show a definite increase in the second stage, due to the disappearance of the nonmagnetic austenite. The other magnetic changes can be unraveled in terms of the stages of tempering, a slight decrease in the first stage and a marked decrease in the third stage being superimposed upon the changes in magnetization normally to be expected with variations in temperature.

There is much significance to the fact that the general slope of the magnetization curve below 500° F. changes from negative or downward (which is normal) to positive or upward (which is abnormal) as the field strength is decreased from 1500 to 265 gauss. This unusual phenomenon is attributable to stress relief, not to structural changes. It is interesting to find such evidence of stress relief at these low tempering temperatures; it undoubtedly plays a role in the toughening and softening tendency of tools which are drawn at low temperatures. Of course, drawing below 500° F. does not achieve anything like complete stress relief. Tempering at higher tem-



peratures provides further stress relief, but does not show on these curves because the structural changes of the second and third stages obscure the magnetic effects of stress. Furthermore, tempering low alloy tools above 500° F. usually cannot be tolerated because of the attendant softening.

It is clear from these "at temperature" measurements that the kinds of changes discussed so far occur during the tempering rather than on cooling from the tempering temperature.

### Time as a Factor — Hardness Changes

All four stages of tempering occur isothermally, being dependent upon time at temperature as well as degree of temperature. Perhaps the best way to demonstrate the quantitative relationship of tempering temperature and time is to plot some readily measured property (like hardness) against a combination of temperature and time, rather than against temperature for a constant time or time at a constant temperature. Hollomon and Jaffe have suggested  $P = T(\log t + c)$  as a suitable tempering parameter, where  $P$  is the "tempering parameter",  $T$  is the absolute temperature ( $^{\circ}\text{F.} + 459$ ),  $t$  is the tempering time (usually in hours), and  $c$  is a constant depending on the steel.

This type of plot is given in Fig. 8 for a series of steels in which the carbon and nickel have been regulated to produce a range of austenite contents after hardening by oil quenching. The constant  $c$  for these steels turn out to be 14.0. The stages of tempering are evident. A small increase in hardness occurs during the first stage as a result of the precipitation from the tetragonal martensite. Following this, the usual softening on tempering sets in, but

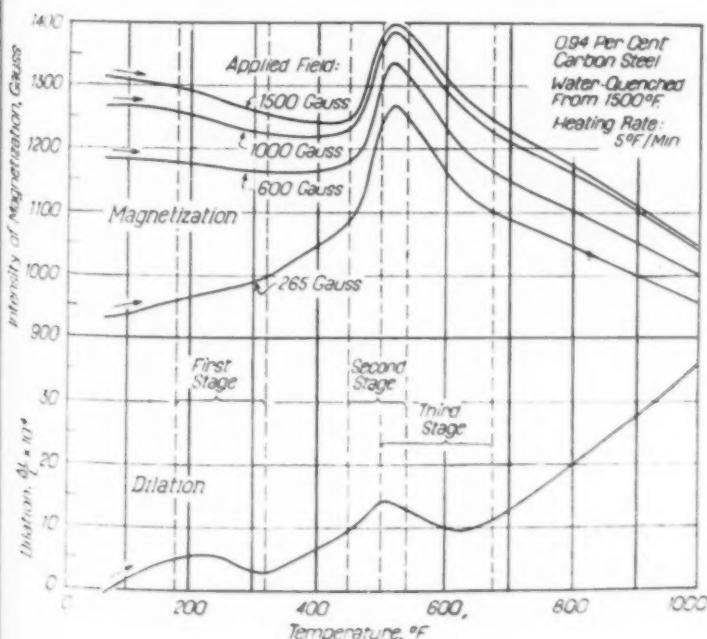
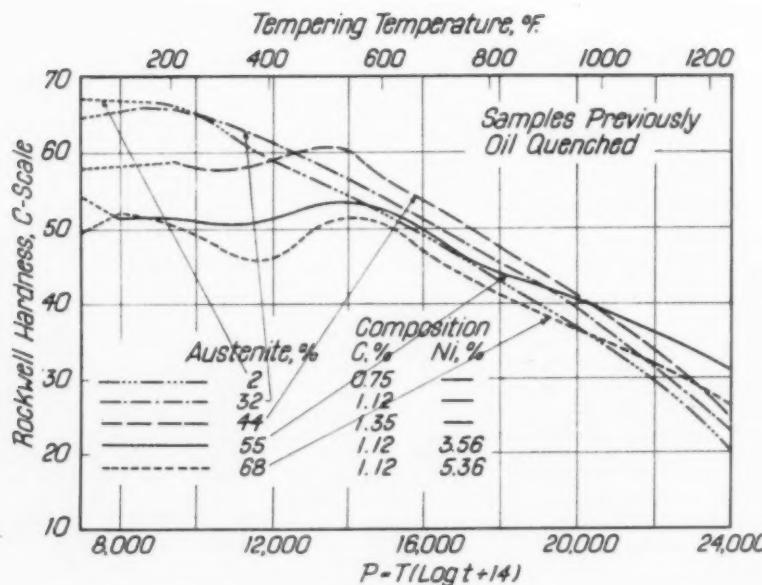


Fig. 7 — Magnetization and Dilation Changes on Heating Hardened Plain Carbon Toolsteel. Measurements made at temperature. Note three stages of tempering and effect of field strength on the magnetic curves. (Antia and Fletcher)



*Fig. 8 — Hardness Versus Tempering Parameter for Five Steels After Ordinary Hardening. (Howard)*

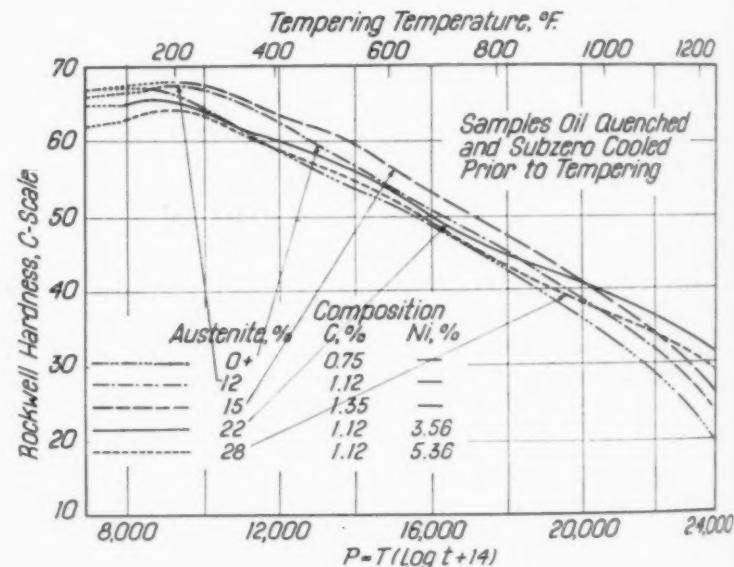
this softening is retarded in the second stage due to the decomposition of the retained austenite. In fact, if there is enough retained austenite, some secondary hardening results. From there on, we find relatively rapid softening during the third stage (and also during the fourth stage, if the latter exists).

From the very nature of these curves, it is evident that each stage can be made to occur at lower temperatures if the tempering time is increased — and the converse is also true. An example of equivalent combinations of temperature and time is given in Table I. It is also clear that the low hardness resulting from large quantities of retained austenite can eventually be compensated for when the austenite is transformed during the second stage of tempering, but the resulting hardness level is too low for most tool applications. Furthermore, even in those steels which have high hardness,

as-quenched, the tempering parameter must be less than 10,000 if the hardness is to be greater than C-65. Under these conditions, the second stage is not completed and therefore some austenite remains in the tempered steel.

It is now well known that subzero cooling of freshly hardened steel can convert a substantial part of the retained austenite into martensite and thereby increase the initial hardness. One might then wonder about the tempering characteristics of such steels after such cold treatment. It turns out that, in principle, the stages remain the same, as indicated in Fig. 9. The cold treated hardness is greater and the corresponding magnitude of the second stage is smaller

*Fig. 9 — Hardness Versus Tempering Parameter for the Same Steels After Subzero Hardening to  $-310^{\circ}$  F. (Howard)*



*Table I — Tempering Combinations for Rockwell Hardness C-65 in 1.1% Carbon Steel*

AFTER ORDINARY HARDENING $P = 10,000$ (FROM FIG. 8)		AFTER SUBZERO HARDENING ( $-310^{\circ}$ F.) $P = 11,000$ (FROM FIG. 9)	
TIME	TEMPERATURE	TIME	TEMPERATURE
0.1 hr.	$310^{\circ}$ F.	0.1 hr.	$385^{\circ}$ F.
1.0	255	1.0	325
10	215	10	285

tenite is transformed during the second stage of tempering, but the resulting hardness level is too low for most tool applications. Furthermore, even in those steels which have high hardness,

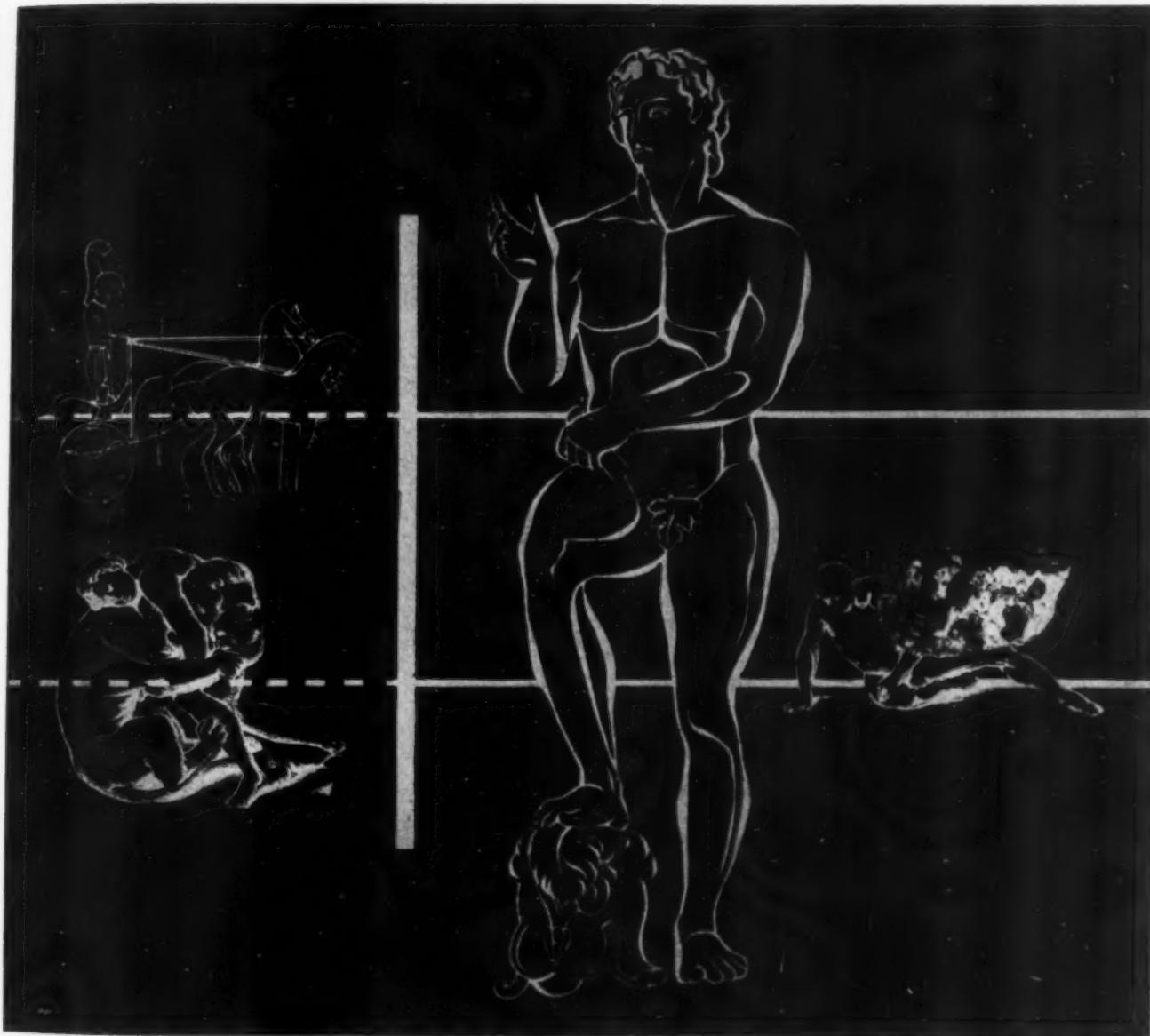
because there is less retained austenite than in the specimens of Fig. 8; in fact, the cold treated hardness is sufficiently high to provide tool steel levels even in the nickel steels. Moreover, as shown in Table I, subzero hardening may permit tempering at higher temperatures (or longer times) than ordinary hardening to attain a given hardness level. According to Table I, C-65 is maintained in the subcooled 1.1% carbon steel after tempering about  $70^{\circ}$  F. higher than is possible with the normally hardened steel.

(Part II will appear in the June issue.)

## IT TAKES MORE THAN MUSCLE

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## PERSONALS

Resigning from the Aluminum Co. of America, Lawrence K. Jetter ♀ has accepted a position as senior metallurgist with the Monsanto Chemical Co., Clinton laboratories, Oak Ridge, Tenn.

Anthony Kuc ♀ has organized Upland Industries, Inc., Upland, Pa., for manufacture of metal stampings and fabrications, and product and manufacturing development.

Irvin H. Schaible ♀, formerly with the Dayton Forging & Heat Treating Co. and U. S. Steel Corp., has become metallurgical engineer of the Apex Machine & Tool Co., Dayton, Ohio.

Calvin W. McKee ♀, previously metallurgical engineer at the Midvale Co., is now process engineer at the Carpenter Steel Co., Reading, Pa.

John N. Lynn ♀, formerly research metallurgist with Rustless Iron & Steel Division and second vice-chairman of the Baltimore Chapter ♀, is now with North American Aviation, Inc., Los Angeles.

After 3½ years with the U. S. Navy as an engineering officer, John J. Demeter ♀ has joined the Nichols Tractor & Equipment Co., Inc., of El Cajon, Calif., as vice-president and plant manager.

Norman C. Silver ♀, formerly at the AC Spark Plug Division, General Motors Corp., has joined his father in operating the Northwest Mineral Sale Co., Minneapolis.

Michiana Products Corp. announces that John H. Staiger ♀ will serve as representative in the Chicago territory and that William A. Zach ♀ will represent the firm in the Indiana territory. Mr. Zach was formerly assistant chief engineer at the Michiana plant.

E. F. Tibbetts ♀, formerly assistant materials engineer for the Shipbuilding Division of Bethlehem Steel Co., has been appointed metallurgical engineer of the Lummus Co., New York City.

James T. MacKenzie ♀ has been appointed technical director of the American Cast Iron Pipe Co., Birmingham, Ala., and his previous position of chief metallurgist has been assumed by Charles K. Donoho ♀, formerly plant metallurgist.

E. G. Jennings ♀, formerly with the Dominion Engineering Works, Ltd., has become sales manager of Metals and Alloys, Ltd., Toronto, Canada.

Willis R. Whitney (honorary member ♀) and Frank N. Speller ♀ were named first recipients of the newly established awards of the National Association of Corrosion Engineers. The two awards were named after them—the Willis Rodney Whitney Award in the Science of Corrosion and the Frank Newman Speller Award in Corrosion Engineering.

L. A. Lindberg ♀, president of Lindberg Engineering Co., Chicago, has united his company with Fisher Furnace Co. and the new combination, to be known as the Fisher Furnace Division of Lindberg, will produce a completely new Lindberg-Fisher induction melting furnace.

Isaac J. Kunik ♀, formerly with the patent department of P. R. Mallory & Co., Inc., has started his own practice in patent, trademark and copyright law in Hartford, Conn.

The Equitable Bearing Co., Inc., Walden, N. Y., announces the appointment of Thomas E. Cushing ♀ as chief engineer. Mr. Cushing has been associated with SKF Industries for the past 21 years.



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<b>PICKLING ACID INHIBITORS</b>
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**Step 3.**

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**Step 4.**

The flange is machined down to the proper height, which automatically removes the slight puckers that appeared on the edge during the previous operation. Top is subsequently polished and nickel plated.

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## PERSONALS

The Steel Improvement & Forge Co., Cleveland, announces the appointment of **David E. Johnson** as vice-president. Mr. Johnson was previously superintendent of production.

**William Marshall Nelson** has joined the technical staff of Traubee Products, Inc., Brooklyn, N. Y., as metallurgist. He was previously associated with Brewster Aeronautical Co. and Reynolds Metals Co.

**Felix E. Wormser** has resigned as secretary and treasurer of the Lead Industries Assoc. to accept an appointment as assistant to the president of the St. Joseph Lead Co.

The Thomas Steel Co., Warren, Ohio, announces the appointment of **George C. Floyd** as manager of operations.

The Dole Valve Co., Chicago, announces that **C. Grindrod**, formerly assistant vice-president in charge of production with Bowser, Inc., has recently joined its organization as plant manager.

**Ralph E. Evarts** has recently joined the Buell Manufacturing Co., Inc., Chicago, as factory manager.

**Orlando P. Metcalf, Jr.** has established Orlando Metcalf and Co., Chicago, offering engineering service and jobbing, and manufacturing products of their own design.

**L. H. McCreery** has been made assistant general superintendent of Moog Industries, Inc., St. Louis, Mo.

**J. S. Hawken**, formerly with Electro Metallurgical Co. of Canada, Ltd., has been appointed control engineer in the London foundry branch of General Steel Wares, London, Ont.

Washington Steel Corp., Washington, Pa., announces the appointment of **Jay W. Stranahan** as district sales manager in Chicago.

**J. D. Adams** Manufacturing Co., Indianapolis, has announced the appointment of **J. G. Frantzreb** as chief metallurgist. He has been with the company since 1936, with an interruption during the war, when he served as captain in the Army Ordnance Dept.

**John L. Abbott** has joined North American Philips Co., Inc., New York, as application engineer in the industrial X-ray division. Mr. Abbott was previously with Wright Aeronautical Corp. as senior metallurgist.

**Louis T. Friedman** is now associated with Molcast Products Co., Newark, N. J.

**Daniel S. Eppelsheimer**, formerly with Metal Hydrides Co., has joined the staff of the metallurgical engineering department at Missouri School of Mines and Metallurgy as associate professor.

Reynolds Metals Co. announces the appointment of **George Perkins** as director of technical service of the aluminum division, Louisville, Ky. Mr. Perkins had previously been a technical advisor of the Reynolds eastern sales divisions with offices in New York City.

**Gordon D. Poole**, formerly district engineer of Canadian Johns-Manville Co., Ltd., has been appointed staff manager of the industrial products division with headquarters at Toronto, Canada.

**James B. Stein** has been assigned to Army Ground Forces, Fort Shafter, Territory of Hawaii, as purchasing and contracting officer and procurement and production control officer after having been released from the Manhattan Engineer District.

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To avoid this expense, the production-minded manufacturer—or the foundryman anxious to produce a quality product and keep customer good will—instigates a system of radiographic spot checking... using Kodak's Industrial X-ray Film, Type M.

#### Why Type M?

Because this particular Kodak Film gives you the best possible rendition of radiographic detail. Because it's as well adapted to inspection of these small alloy castings with 100-kv equipment as to inspection of heavy alloy parts with million-volt equipment.

#### The economical way to assure continuous production flow

Used in foundries to test efficiency of experimental casting technics, soundness of new designs... or in machine shops to "screen out" faulty parts before machining... radiography has more than paid its way in hundreds of plants. No reason why it won't in yours! Ask your x-ray dealer for information, or write...

**Eastman Kodak Company**

X-ray Division • Rochester 4, N. Y.

## Radiography

...another important function of photography

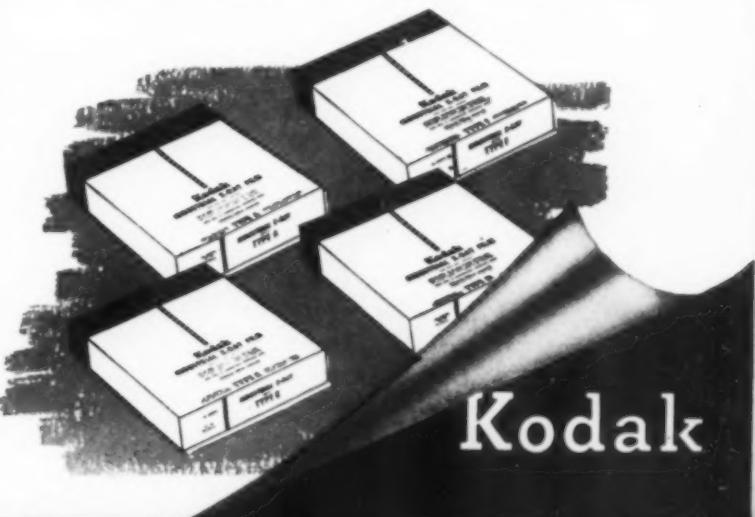
**Internally sound castings,  
ready for machining**

#### Other Kodak X-ray Films for industry

**Kodak Industrial X-ray Film, Type A**... most often used for light alloys at lower voltages and for million-volt radiography of thick steel and heavy alloy parts.

**Kodak Industrial X-ray Film, Type F**... with calcium tungstate screens—primarily for radiography of heavy steel parts. The fastest possible radiographic procedure.

**Kodak Industrial X-ray Film, Type K**... primarily for gamma- and x-ray radiography of heavy steel parts, or of lighter parts at limited voltages where high film speed is needed.



**Kodak**

## PERSONALS

The Tocco division of the Ohio Crankshaft Co., Cleveland, announces that **George E. Ebbeler** has been appointed sales engineer to cover Wyoming, Nebraska, Iowa and central Illinois, and that **L. T. Martensen**, formerly at Republic Tool & Drill Co., will be sales engineer for the Kansas, Missouri, Oklahoma, Arkansas and southern Illinois territory.

**John J. Hauptly** has been promoted by Joseph T. Ryerson & Son to the position of sales representative for alloy and toolsteels in the New York City area.

**J. Jerome Pierce**, formerly with Triplett & Barton, Inc., has joined the Naval Ordnance Laboratory at White Oak, Md., as chief of interpretation and standards section.

**Kenneth R. Wood**, formerly with the Aero Division of Minneapolis Honeywell Regulator Co., has joined Dur-O-Lite Pencil Co., Chicago, as works manager.

**Keith Whitcomb**, formerly research chemist of Cee-Bee Chemical Co., Los Angeles, has been named technical director of the company.

**Charles G. Purnell** has recently rejoined Carnegie-Illinois Steel Corp. as development representative in the market development division.

**P. Trapp** has retired from the Gorham Manufacturing Co. after 35 years with the organization.

The Crucible Steel Co. of America, announces the appointment of **Ward Jenks** as manager of the forge blisks department at the Midland works. Mr. Jenks has been connected with the Detroit offices of the company since 1936.

**Norman Arnold Nielsen**, metallurgical engineer of the engineering research laboratory of the Du Pont Co.'s experimental station, Wilmington, Del., has been awarded the 1946 Young Authors' Prize of the Electrochemical Society for the best technical paper of the year in the publications of the society.

**George H. Galbraith** has secured a leave of absence from Shell Oil Co. of Canada, Ltd., to continue his studies at the University of Toronto.

**Waldemar Naujoks**, formerly chief engineer of Steel Improvement & Forge Co., Cleveland, has been elected president of the Bison Forge Co., Inc., Buffalo, N. Y., and will become a partner in the company.

Jessop Steel Co., Washington, Pa., announces that **A. J. Fischer** has been appointed manager of the carbide and cast alloy division. Mr. Fischer was previously assistant to the supervisor of carbide production at Firth-Sterling Steel Co.

**Henry Dahlquist**, senior member of the firm of Dahlquist & Brengle, will sail to Europe in June for an extended visit to Sweden, Norway, Denmark, England and France, investigating market possibilities and contacting firms desiring representation in this country.

**John H. Adams, Jr.**, formerly welding engineer and assistant metallurgist at the New York Ship Yards, has been named research metallurgist and assistant to the director of the Nelson Research Laboratory, Villanova, Pa.

**Robert H. Frazier**, formerly a metallurgical engineer with the National Tube Co., has joined the staff of Battelle Memorial Institute, Columbus, Ohio, where he will be engaged in research in steel processing.

**A PRECISE HARDNESS TEST**

**of Microscopic Particles**

Tin Oxide Crystal,  
magnification 1000X.

WITH a Spencer Bierbaum Microhardness Tester you can measure accurately the hardness of small areas, particles, and microscopic constituents of metals.

The specimen, highly polished and lubricated, is moved by micrometer feed beneath an accurately ground diamond point. The point is cube shaped for durability and ease of duplication. Pressure is precisely controlled so that hardness can be determined under the microscope by measuring the width of the resulting cut.

The Microhardness Tester is recommended for use with Spencer Metallurgical Microscopes. For further information write Dept. S119.

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## AIR COMPRESSOR LUBRICATION

# Solving AIR COMPRESSOR TROUBLES

**Lubrication Engineer's Report:** "A mining company\* in the Joplin area was having trouble with the unloading valve on an Angle Compound Air Compressor. They were also troubled with discharge valve breakage of the high pressure cylinder.

"The previous oil was replaced with Cities Service North Star Oil No. 5 and not a single instance of gumming or sticking or trouble of any kind with the unloading valve No. 1: or discharge valve has been reported in over two years."

"A utility plant\* in Springfield, Mo., uses compressed air from a single stage belt-driven air compressor in connection with overhauling jobs of the boilers in their plant. They are all of the water tube type and are

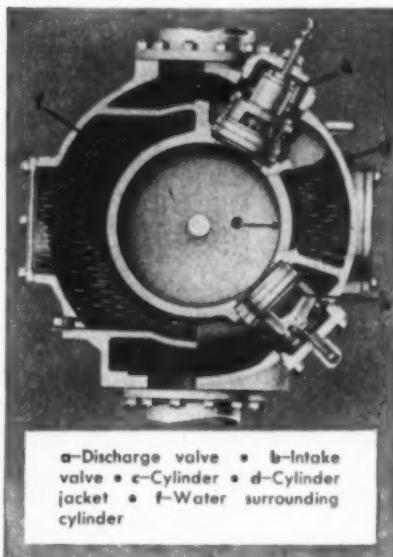
**Case No. 2:** overhauled at regular intervals. During these overhauls they need a constant supply of air. The unloading valve of this compressor would gum up to the extent that they would have to clean it about every other day when using a competitor's oil. I sent them a drum of Cities Service North Star Oil No. 5 about a year ago, and checked with their Chief Engineer last month.

He tells me they haven't had to clean the unloading valve since putting in the North Star Oil."

"We have lubricated a 1000 cubic foot two-stage air compressor in the Mid-Continent area for over three years.

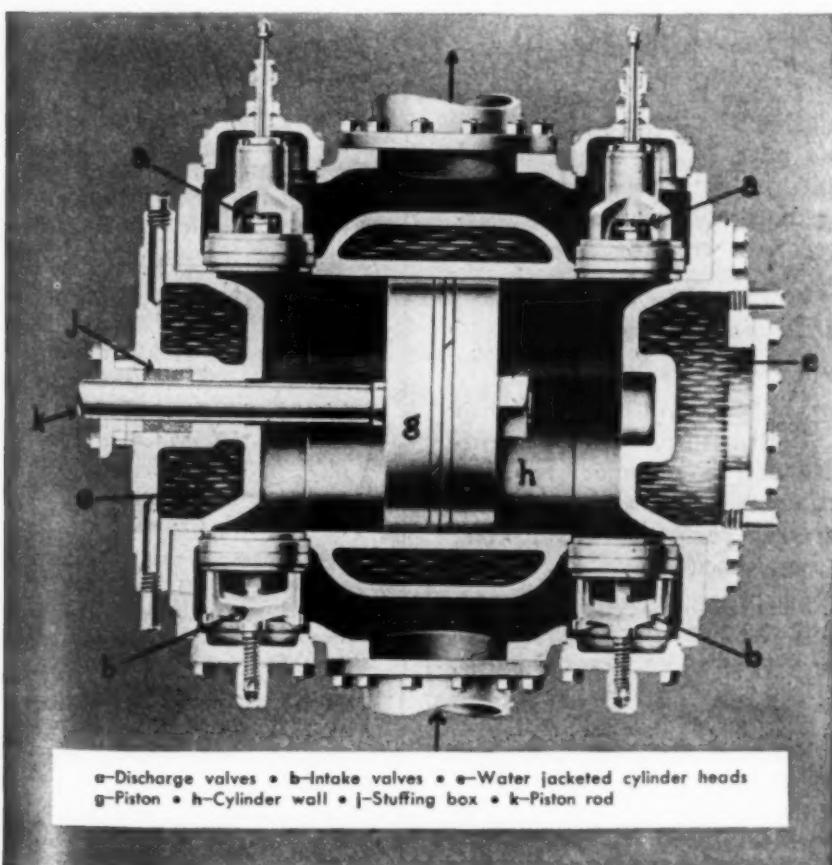
The customer\* says that in **Case No. 3:** Oil No. 5 in this compressor he hasn't had any valve breakage and that carbon deposit on valves and seats has been down to practically nothing."

\*Names on request.



Solving compressor operating problems has been Cities Service's special forte for years. A phone call or card-to the Cities Service office nearest you will bring this engineering experience to your plant. There is no obligation. For useful information that every air

**Free Booklet:** compressor owner and operator should know, write for our free booklet, "Air Compressor Lubrication." Cities Service Oil Co., Sixty Wall Tower, New York 5, N. Y., Room 80.



**Cities Service means Great Service**

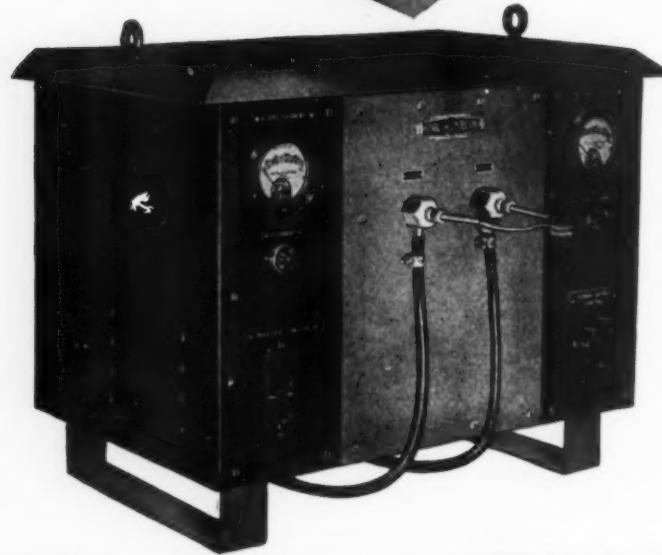
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Cities Service Oil Co.  
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Arkansas Fuel Oil Co.  
SHREVEPORT, LA.

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**\$650**



Never before a value like this new 2-KW bench model "Bombardier" or high frequency induction heater . . . for saving time and money in surface hardening, brazing, soldering, annealing and many other heat treating operations.

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Economical Standardization of Unit  
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Scientific Electric Electronic Heaters are made in the following range of power: 1-3-5-7 $\frac{1}{2}$ -10-12 $\frac{1}{2}$ -15-18-25-40-60-80-100-250KW. — and range of frequency up to 300 Megs. depending on power required.

**Scientific Electric**  
DIVISION OF  
"S" CORRUGATED QUENCHED GAP CO., 119 MONROE ST., GARFIELD, N.J.

## PERSONALS

George W. Billings, Jr.,  $\ominus$  has joined the Universal Zonolite Insulation Co. as research metallurgist.

Donald R. Mathews  $\ominus$ , on his release from Army service, has joined the Allen-Bradley Co., Milwaukee, as assistant metallurgist.

Charles E. Martin  $\ominus$ , formerly welding engineer for Miller Electric Co., has joined the staff of the general engineering department of Purdue University, Lafayette, Ind., as instructor in electric arc welding.

F. W. Schonfeld  $\ominus$  has resigned from the position of assistant professor of physical metallurgy at State College of Washington and is now employed by the University of California at the Los Alamos Scientific Laboratory.

Herbert E. Weber  $\ominus$ , formerly metallurgist at Universal-Cyclops Steel Corp., is now senior metallurgist in the materials evaluation unit at Wright Aeronautical Corp., Wood Ridge, N. J.

J. E. Reynolds, Jr.,  $\ominus$ , formerly metallurgist with Continental Gin, Birmingham, Ala., has resumed graduate studies at the Missouri School of Mines and Metallurgy as a graduate assistant in the department of metallurgical engineering.

George F. Meyer  $\ominus$ , formerly plant metallurgist with Shakeproof Division of Illinois Tool Works, has been appointed plant superintendent at Wilson Steel and Wire Co., Chicago.

After receiving his M.S. in metallurgy from the University of Notre Dame, John P. Sheehan  $\ominus$  has accepted a position as associate metallurgist at Armour Research Foundation, Chicago.

Hans R. Stephan  $\ominus$  has accepted a position as metallurgist with the Fairchild Engine and Airplane Co., Nepea Division, Oak Ridge, Tenn.

The International Harvester Co. has promoted J. H. Robinson  $\ominus$  from assistant works metallurgist at the Milwaukee plant to works metallurgist at Springfield, Ohio.

After recent discharge from the Army and postgraduate work at the University of Illinois, Robert C. Schueler  $\ominus$  has accepted a position with the Chemcel plant of the Celanese Corp. of America at Bishop, Texas.



## The pause that...UPSETS can occur in your processes too.

The surest way to avoid trouble is never to let things get out of hand.

This is the basis of the "Continuous Balance" concept in measurement and control of industrial processes. Instantaneous detection and correction of the slightest change prevents any appreciable change from occurring. Secondary reactions never have a chance. Process upsets never occur.

The important fact is that "Continuous Balance" measurement and control is simultaneous with temperature changes. This is why intermittent or "nudging" controllers cannot handle today's process control requirements.

In the Brown ElectroniK Potentiometer which is the only instrument operating on the "Continuous Balance" principle, there are no intervals. There are no pauses. Just smooth instantaneous regulation of process conditions.

The Brown ElectroniK Potentiometer with the well-known Air-o-Line control unit provides everything that is desired in process control.

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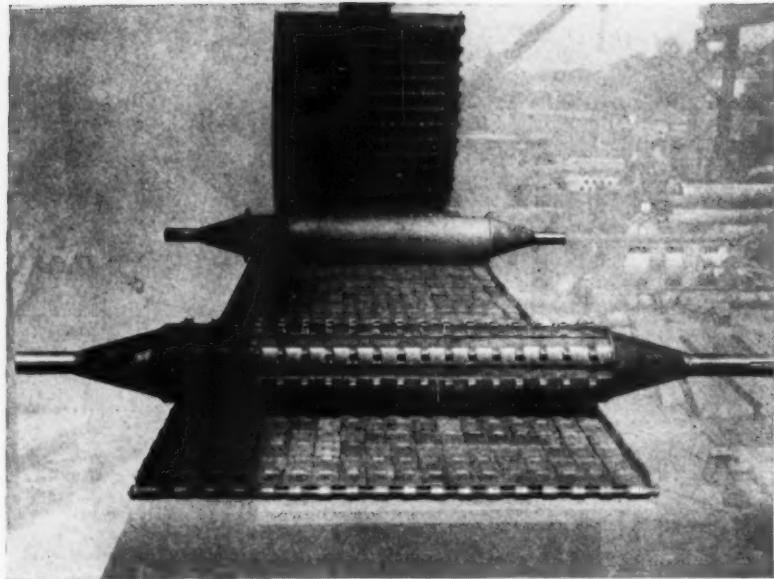
**ElectroniK Potentiometer  
with Air-o-Line Control.**

This instrument is described in detail in Catalog 15-4. A copy will gladly be sent to you without obligation. Write today.

**BROWN** *ElectroniK* **POTENTIOMETERS**



**HERE'S  
ONE OF OUR  
MORE DIFFICULT JOBS**



It's a conveyor assembly for a heat-treating furnace, alloyed and cast for a large manufacturer of automobile parts. Perhaps you would be interested in some facts:

Alloying Elements . . . 15% Chromium, 35% Nickel  
 Conveyor Belt . . . 8,400 pounds, statically cast  
 Head Shaft . . . . . 1,625 pounds, centrifugally cast  
 Tail Shaft . . . . . 804 pounds, centrifugally cast

The belt consists of several thousand individual links assembled and held together by alloy steel rods. No machining of the links was necessary. The lugs on the head shaft were cast integrally with the shaft. The end cones on both shafts were cast statically and then welded on.

You may not need a conveyor for a heat-treating furnace such as this, but if you need any high alloy casting—for resisting heat, corrosion or abrasion—we would like to discuss producing it for you. Our experience in static castings goes back to 1922 and in centrifugal castings back to 1931, both pioneering dates.

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**PERSONALS**

Clee O. Worden, Jr.,  $\ominus$ , has joined the Carl A. Zapffe consulting laboratory as associate research metallurgist. He was previously in the research departments of Rustless Iron and Steel Division, Naval Research Laboratory, and Glenn L. Martin Co.

M. F. Surls  $\ominus$ , formerly metallurgist with the Clark Equipment Co., has joined the staff of the Charles C. Kawin Co., Chicago, as metallurgist.

Paul Schick  $\ominus$ , who has been with the Carboly Co. for the past five years, has been appointed sales engineer for the company in the Philadelphia area.

Raymond L. Phebus  $\ominus$ , formerly associated with the Glenn L. Martin Co. and the Rustless Iron and Steel Division of the American Rolling Mill Co., has joined the staff of the research laboratory of Carl A. Zapffe, Baltimore, Md.

Dwight M. Wilkinson  $\ominus$ , formerly chief engineer of Industrial Ovens, Inc., has become president of Ovens for Industry, Inc., Cleveland.

The American Rolling Mill Co. announces the appointment of Olney Broun  $\ominus$  as assistant general superintendent of the Rustless Division, Baltimore, Md. Mr. Broun has been with Rustless since 1936 and has been superintendent of the production metallurgical department since 1940.

G. H. Clamer  $\ominus$ , past president and honorary member of the A.S.T.M., gave the dedicatory speech at the formal opening of the new A.S.T.M. headquarters building on Race St., Philadelphia.

J. M. Blalock, Jr.,  $\ominus$ , formerly on the staff of Battelle Memorial Institute, has become associated with the Baker and Adamson Sales Division of General Chemical Co., Oxford, N.C.

On his return from service in the Navy, Edward J. Stuber  $\ominus$  assumed the position of contracting engineer in the fabricated steel division of the Bethlehem Pacific Coast Steel Corp., Alameda, Calif. He had been in the metallurgical department of the Lackawanna plant of Bethlehem Steel before entering service.

A. J. Nordenson  $\ominus$ , formerly Southwest district manager for Mahr Manufacturing Co. and J. T. Thorpe, Inc., at Houston, Texas, is now at the Los Angeles office of J. T. Thorpe, Inc.

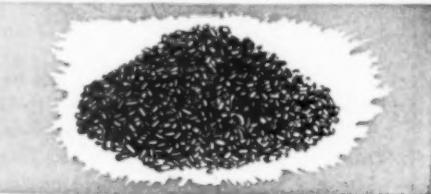
# POUND FOR POUND...

...get 3 times as many finished parts!



R317-T can be run at high-profit speeds, comparable or in some cases, higher speeds than brass.

#### CLOSER TOLERANCES



R317-T machines easily to a bright, natural finish. Forms small chips. Does not run with the tool. May be worked to very close limits.

#### LOWER-COST MACHINING



Accurate volume production with fewer rejects. Result: lower cost, more profit per finished part.

Yes—thanks to the favorable weight factor aluminum gives you three times as many finished parts per pound as brass.

By the foot you pay less for aluminum than you do for brass. All of which adds up to a saving of about 50% in material cost.

For high speeds, excellent machinability, a bright, natural machine finish and LOWER COSTS, use R317-T, Reynolds new aluminum screw machine stock. Only a fraction of the cost per finished piece as R317-T weighs only  $\frac{1}{3}$  as much as brass (and other heavy non-ferrous metals).

Order now. R317-T is ready for immediate shipment from Louisville warehouse stock in rounds and hexagons in all standard sizes. 17S-T, Reynolds standard screw machine stock, is also available now.

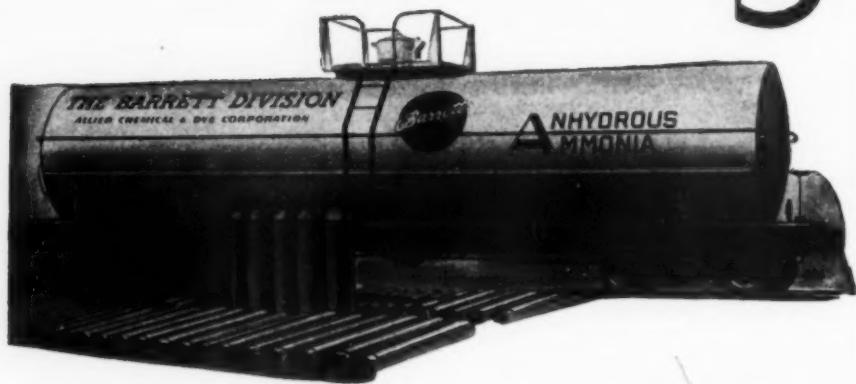
Consult Reynolds. Reynolds is ready to work with your engineers. Offices in principal cities. Phone nearest office . . . or write Reynolds Metals Company, Aluminum Division, 2519 South Third Street, Louisville 1, Kentucky. See Sweet's or write for Catalog 100-B "Reynolds Aluminum—Available now for Today's Products."



# REYNOLDS ALUMINUM

# Your best source of

NH<sub>3</sub>

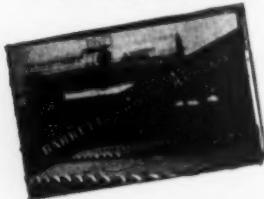


**Barrett** standards of consistent purity, uniform dryness, speedy deliveries and dependable service make Barrett Anhydrous Ammonia your best source of NH<sub>3</sub>.

**Barrett Anhydrous Ammonia** is available in two grades: REFRIGERATION GRADE, guaranteed minimum 99.95% NH<sub>3</sub>; and COMMERCIAL GRADE, guaranteed minimum 99.5% NH<sub>3</sub>. Both grades are shipped in tank cars with a capacity of approximately 26 tons of NH<sub>3</sub>. REFRIGERATION GRADE only is also packaged in 25, 50, 100 and 150-pound standard-type cylinders and in 100 and 150-pound bottle-type cylinders.

**Barrett Anhydrous Ammonia** must pass rigid tests for moisture, non-condensable gases and other impurities, before release for shipment. Cylinders and tank cars are thoroughly cleaned and inspected, upon return to the plant, before reloading.

**Barrett Anhydrous Ammonia** is stocked in cylinders at points conveniently located from coast to coast. The advice and help of Barrett technical service men are available to you for the asking.



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ALLIED CHEMICAL & DYE CORPORATION  
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## PERSONALS

Lewis W. Schmitt ♂ has been appointed branch manager of the Electric Steel Foundry in Sacramento, Calif., from which office he will service northern California and the state of Nevada.

H. L. Stackhouse ♂ has been transferred by General Foods Corp., from the Post Cereals Division, Battle Creek, Mich., to the New York City offices of the corporation where he will be chief design and construction engineer.

Garrett B. LeVan ♂ has been appointed assistant general manager of the Cyclops Division of Universal-Cyclops Steel Corp., Titusville, Pa.

C. Donald McLain ♂, formerly sales engineer with the Goslin-Birmingham Manufacturing Co., is now employed by the Industrial Metal Protectives Corp. of Virginia as sales engineer.

W. P. Wallace ♂, formerly division metallurgist for the Columbia Steel Co., has joined the department of engineering, University of California, Los Angeles, as lecturer in engineering. While at the university, he will continue work toward an advanced degree.

George L. C. Dehn ♂ has been appointed branch manager of the Magnaflux Corp. for the Southwestern district with offices in Dallas, Texas. He had previously been field engineer of Magnaflux in the Chicago and New York areas.

Louis A. Luini ♂ has joined the staff of the United States Steel Corp.'s Research Laboratory in Kearny, N. J., after resigning his position as metallurgist with Wright Aeronautical Corp.

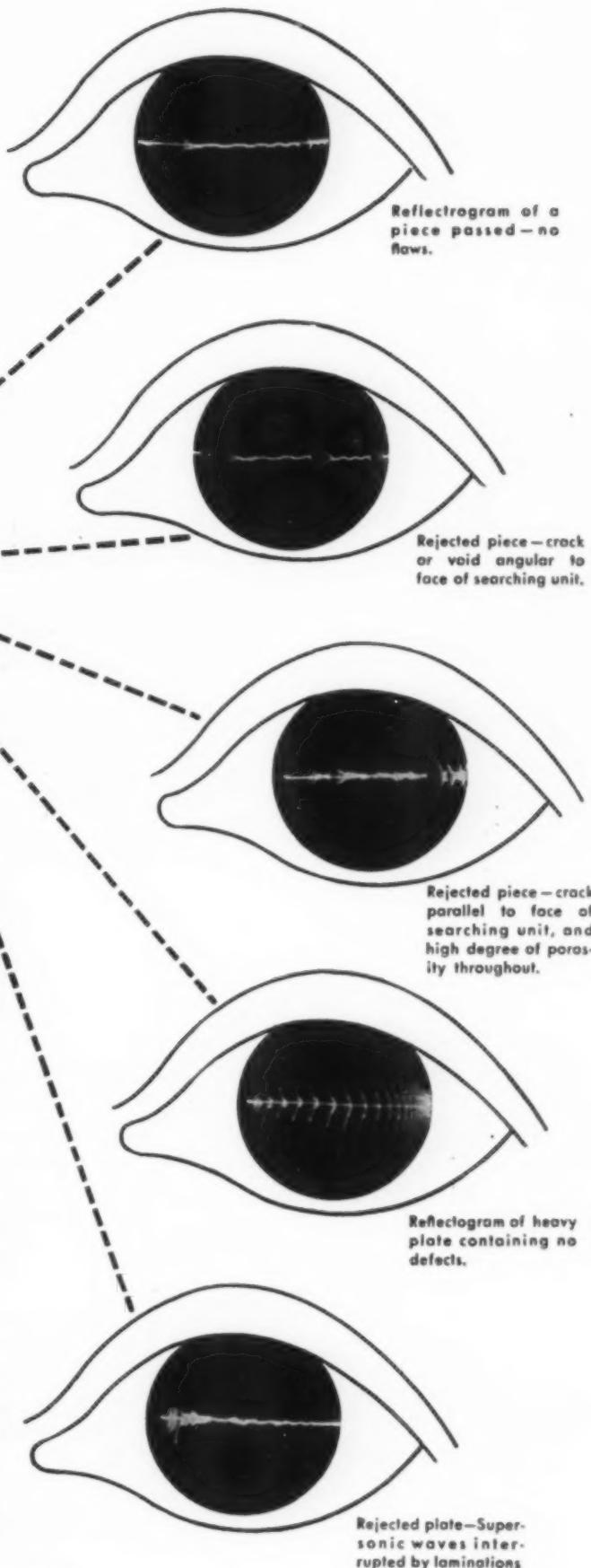
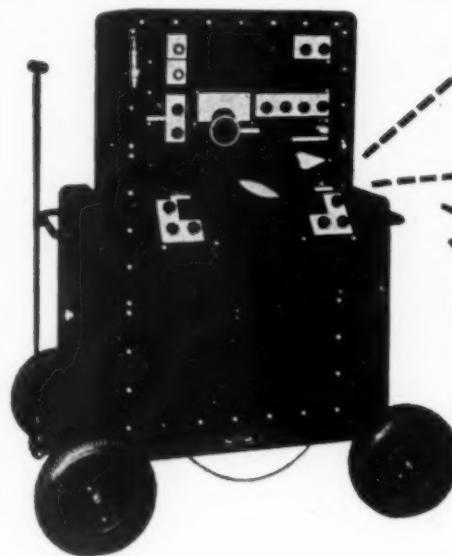
Price B. Burgess ♂, formerly assistant research metallurgist at Wyman-Gordon Co., is now instructor in the foundry section of the department of metal processing, University of Michigan, Ann Arbor, Mich.

Earle L. Fredine ♂, formerly chief quality control engineer of the Collins Radio Co., has accepted the position of assistant chief engineer of the communications division of the Galvin Manufacturing Corp., Chicago.

Paul M. Haenni ♂, formerly director of research of the Kingston laboratory of Aluminium Laboratories, Ltd., has been appointed director of Aluminium Limited's Training School in Geneva, Switzerland.

# Supersonic "EYES" for Industry

Inaudible sound waves generated by Sperry's Supersonic Reflectoscope "see" internal flaws instantly



Accurate, instantaneous location of internal defects—flaws that may cost you time and money in machining apparently good material—is made possible through Sperry's Supersonic "eyes". These typical oscilloscope patterns from a Sperry Supersonic Reflectoscope show how it provides industry with better quality control through non-destructive sonic testing.

Already in wide use throughout industry, the Supersonic Reflectoscope is daily finding increased acceptance because it locates *smaller* defects and penetrates *deeper* than any other non-destructive testing device... because it finds flaws *instantaneously*... eliminates long delays while waiting for results.

Safe to operate and easy to handle, the portable, 175-lb. Sperry Reflectoscope can be brought right to your job—can make your internal testing of metals and other materials rapid, effective and economical. Write today for bulletin and technical data sheets which will help you solve your quality control problems.



**SPERRY PRODUCTS, INC.**  
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SP-104

# "Let's Look at The Records"



A recent report contains records of MICHIANA Retorts in service in a large eastern plant for calcining paint pigments.

Retort No.	Total Hrs. To Date	Condition	Probable Total Hrs.
A-5115	8,728	Good	15,000
A-1609	13,835	Good	15,000
92279	18,089	Good	20,000
86619	26,700	Good	30,000
A-1607	12,351	Good	15,000
A-1608	12,977	Small hole	13,200

## Long Heat-Hour Service a Michiana Characteristic

MICHIANA for over a quarter of a century has proven that the uniform characteristics mean more heat-hours—and their dependability permits users to plan and expect definite performance.

From laboratory, through the hands of experienced foundrymen—to final inspection—your order is under the supervision of competent metallurgists.

Among the many regular users of MICHIANA Alloy products are the leaders in U. S. industry—concerns that recognize the savings possible in uniformly better performance and assured long heat-hour service.

MICHIANA can meet your particular needs—in size and alloy characteristics. Now is the time to survey your requirements and prepare for steady production. Let us make recommendations and quotations. MICHIANA PRODUCTS CORPORATION, Michigan City, Indiana.



Send for your copy of  
Bulletin 110 today.

**MICHIANA**  
Heat-Resistant and  
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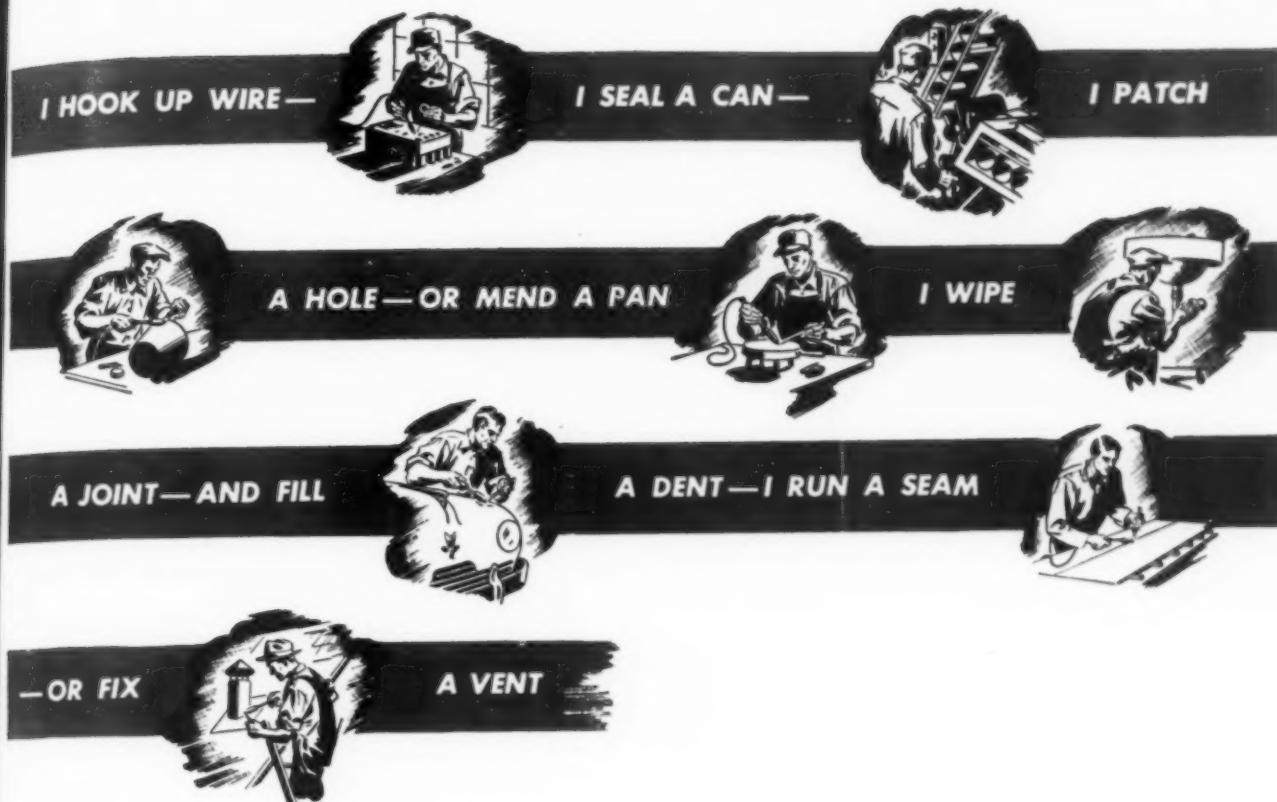
## TINNING CAST IRON\*

THE poor tinning quality of cast iron is caused mainly by the presence of graphite flakes and is intensified by contamination of the iron surface by graphitic sludge after pickling in acids. Investigation of modifications of the ordinary tinning processes shows that improved tin coatings can be obtained by reducing acid pickling to a minimum; this is facilitated by good mechanical cleaning. Decarburizing is also advantageous if the scale is afterward removed by shotblasting. The best pickling agent proved to be a cold mixture of 5% by volume sulphuric acid and 5% hydrofluoric acid. Irons with over 2.7% silicon or over 3.5% carbon—and particularly annealed irons—are of inferior tinning quality, but this is much less noticeable when improved tinning procedures are used. However, the corrosion resistance and adhesion of coatings obtained by such modifications of ordinary methods are still low.

Treatment of cast iron in fused salts, as an alternative to the processes of degreasing, pickling and fluxing in aqueous solutions, was investigated. In the fused chloride method, the iron is first mechanically cleaned by machining, grinding, sand or shot blasting. The article is then immersed in a fused zinc chloride, sodium chloride eutectic mixture at 570 to 660° F. and held for 20 to 40 sec. after the envelope of solid salt formed around the article melts. It is then dipped in tin, covered with a layer of the same fused salt mixture at 570° F. If a bright and corrosion resisting tin coating is required, the article may be dipped in a second tin bath covered with a suitable oil. Corrosion tests showed greatly reduced porosity of the coating after treatment in the fused chloride bath as compared with standard procedures or with the improved procedures described above.

Adhesion tests on a series of cast iron bearing shells tinned by a number of different procedures and lined with a white metal bearing alloy indicated that the adhesion values obtained after use of the fused chloride (*Cont. on p. 804*)

\*Abstracted from "The Tinning of Cast Iron", by R. A. Creswell, British Iron and Steel Institute, Advance Copy, Feb. 1946.



## what am I?

► I'm a low-melting, free-flowing alloy that bonds quick as a wink. Know me? I come from a complete line of non-ferrous metals and alloys you can get easily anywhere in the United States. Know me now? I'm solder, of course. Federated solder.

And each Federated solder is but one of a tremendous family of "joiners". Federated solders are supplied in all commercial forms and compositions. Federated solders are made to fit the job—to provide low-melting, quick-freezing, a specific plastic range, or other required properties.

This complete line is your assurance that Federated can supply you with the exact solder in the form you need. And Federated's technical representatives are glad to help you solve industrial soldering problems. For information and prices, call or write

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**Federated** METALS DIVISION  
AMERICAN SMELTING AND REFINING COMPANY

JOURNAL E-118



## TINNING

(Cont. from p. 802) method are consistently superior to those obtained by pickling procedures:

TREATMENT	RANGE OF VALUES
Standard tinning	0 to 4030 psi.
Mixed acid pickling and tinning	0 to 4030
Copper-plated and tinned	0 to 5825
Iron-plated first	2015 to 7170
Electrotinned	0
Tinned by fused chloride method	4480 to 6270

The only process giving higher adhesion values is the preliminary electrodeposition of iron which introduces operational disadvantages. The chloride method can be adapted to tinning by wiping, although somewhat lower adhesion values are obtained.

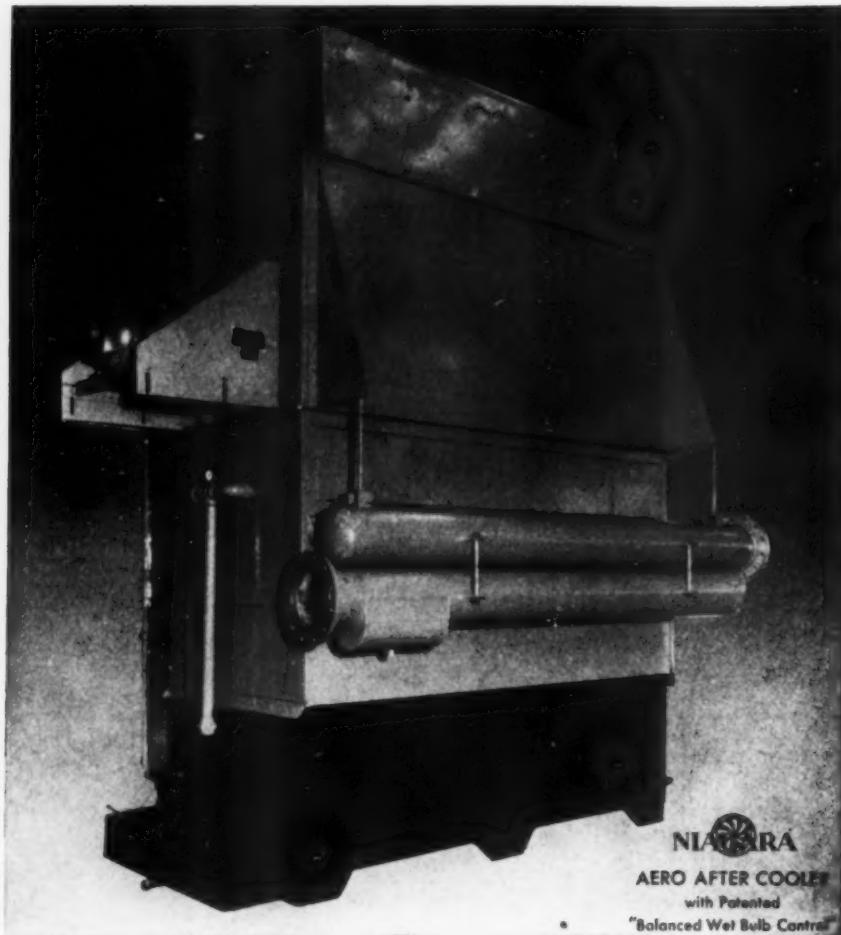
A nitrate method was developed to give highly adherent coatings of tin. It involves the following steps: light pickling in acid to "open up" graphite flakes; immersion for 15 min. at 570 to 660° F. in fused sodium nitrate, potassium nitrate eutectic mixture to oxidize surface graphite; pickling in dilute hydrofluoric acid to remove the scale formed in the nitrate bath; fluxing in an aqueous solution of the zinc chloride, sodium chloride eutectic; and tinning. The adhesion values were superior to those obtained by using the chloride method, being consistently about 6720 psi. Microscopic examination of the bond showed that the tin penetrated the cavities formerly occupied by graphite.

Both fused salt methods of tinning have been used successfully on an industrial scale. On the whole, the nitrate process is preferred for tinning cast iron by dipping and the chloride process for tinning by wiping, but the chloride process is satisfactory for dip tinning when the castings are sound and well cleaned mechanically. Either process can be used satisfactorily for coating cast iron with tin-lead alloys by hot dipping.

## WELDED PIPE\*

MASS PRODUCTION of large-diameter pipe by a special forming-welding-sizing process is the culmination of a gradual change in pipe-line practice. (To p. 806)

\*Abstracted from "40-Ft. 1,000-000-Amp. Butt Weld". *Steel*, Feb. 4, 1946, p. 120 to 123; 158 to 160.



## Save expensive "wear out" of air tools

● Water in compressed air lines is more than a nuisance; its cost is thousands of dollars yearly in worn-out tools and equipment, or broken air tools caused by water hammer, abrasion and washed-out lubricants.

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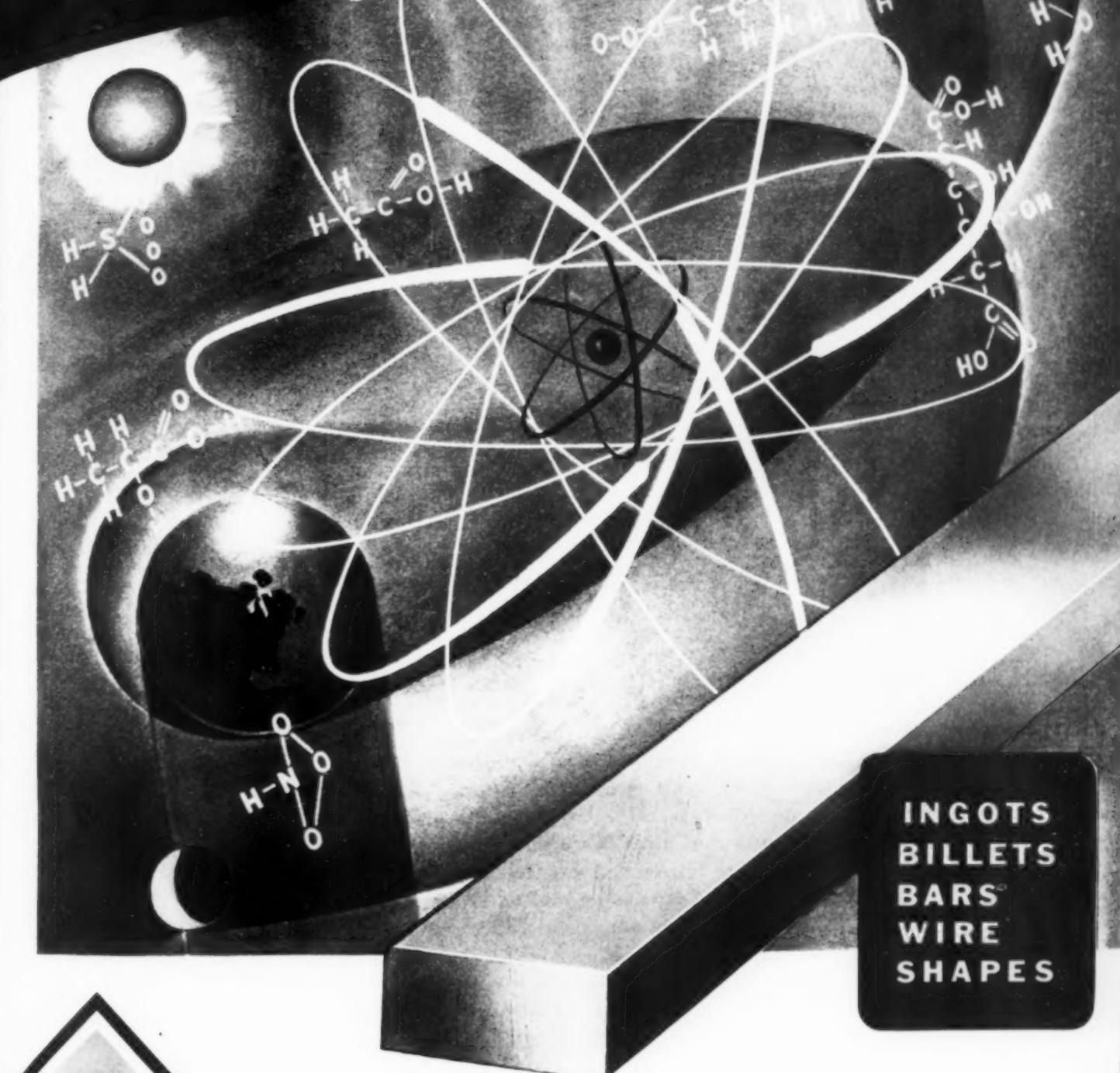
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## WELDED PIPE

(Continued from p. 804) Since the introduction of welded pipe by the A. O. Smith Corp. in 1927, working stress has increased from 10,000 to 40,000 psi. and the safety factor on yield strength has been reduced from 4 to 1½.

The improved pipe is made from rolled steel (skelp) with 0.20 to 0.30% carbon. The use of rolled steel offers many advantages: uniform thickness, desirable smoothness and density, easy inspection of both surfaces before manufacture, and the ability to make thin-walled pipe as readily as heavy-walled. Skelp with a uniform length of 40 ft. is pickled, inspected, and then scarfed and flattened. It is formed to a roughly tubular section in a series of three hydraulic presses. The edges are then welded together in a 1,000,000-amp. flash welding machine.

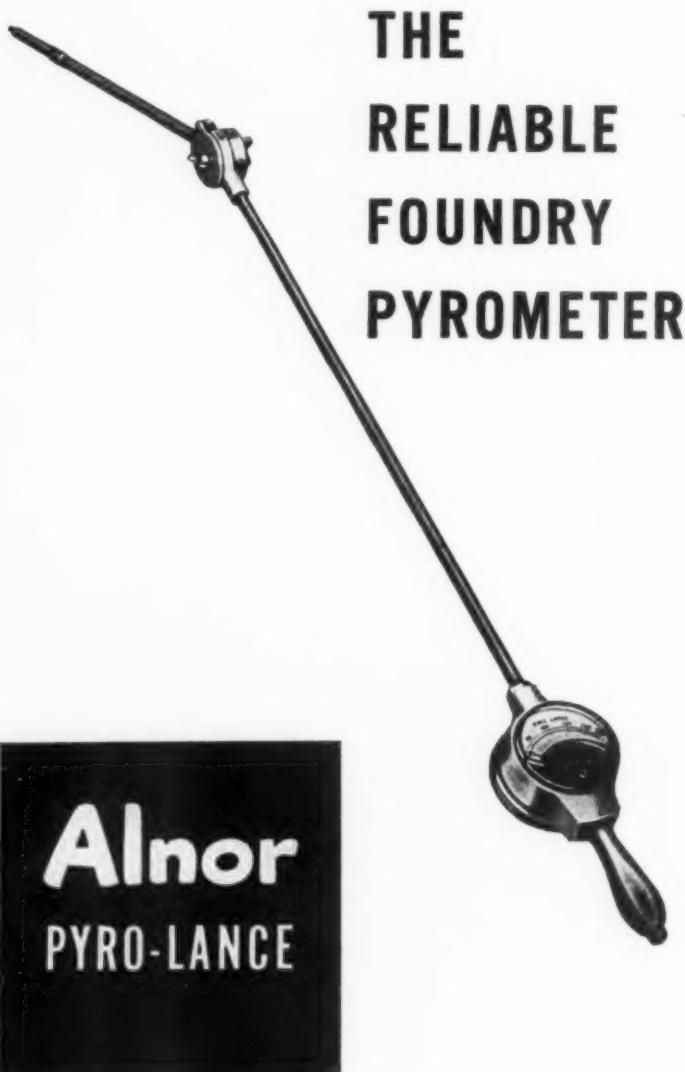
The uniformity of the weld is assured by automatic control of the welding. After the flash is trimmed internally and externally by a cutting tool, the pipe is subjected to an internal hydrostatic pressure sufficient to stress the steel beyond its yield point. This operation tests the strength and soundness of the weld, and makes the pipe round, straight and of the correct diameter. The major advantage of the hydrostatic operation is that it cold works the steel, raising its yield strength and thus considerably increasing its capacity to withstand internal pressures.

In the final testing machine, the pipe is subjected to a hydrostatic pressure while repeated blows are struck on the weld area by hammers. This test is conducted primarily to comply with A.P.I. specifications but at the same time is an inspection for leaks and a check on the resistance of the weld to shock under pressure.

## WHAT IS A LUBRICANT?\*

ALTHOUGH a lubricant may be simply defined as a substance which will reduce the friction between one object and another in contact with it, (Cont. on p. 808)

\*Abstracted from paper presented by Henry E. Mahncke at the 1946 Spring Meeting of the American Society of Lubrication Engineers.



The Alnor portable Pyro-Lance is a rugged, durable, portable pyrometer built with shock-resisting movement and enclosed extension thermocouple. It stands up in foundry service and gives the accurate temperature readings essential to low-cost production of sound castings. Especially suited for use on molten brass, bronze, copper, aluminum bronze, magnesium alloys, and similar metals where temperatures are not over 2300° F. Long life, enclosed thermocouple takes true readings below the surface, unaffected by dross or surface conditions.

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For further information, write for the booklet, "HAYNES Precision Castings."

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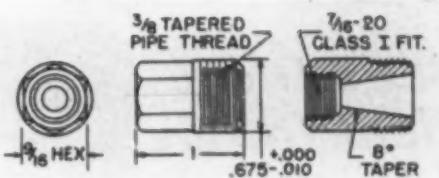
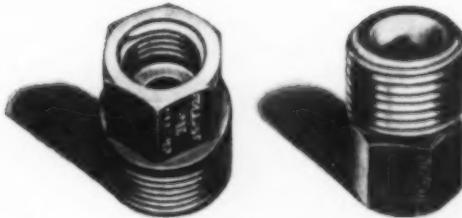
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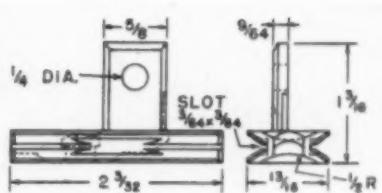
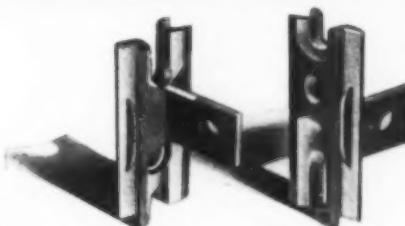
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The registered trade-marks "Haynes", "Haynes Stellite", and "Hastelloy" distinguish products of Haynes Stellite Company.



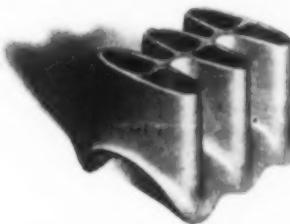
1. PART: Spray Nozzle Body

Machining this part from bar stock is more expensive than precision casting it from corrosion-resistant HASTELLOY alloy C.



2. PART: Reciprocating Slide

Precision casting this slide, used in cloth-cutting machinery, from HAYNES STELLITE alloy No. 6 saved 42 machining operations.



3. PART: Jet Outlet Nozzle

This part is precision-cast of HAYNES STELLITE alloy No. 21 because it did not hold its shape when fabricated from sheet metal.

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INSTALLED**



M-32

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ELYRIA, OHIO.

## WHAT IS A LUBRICANT?

(From p. 806) and in motion with respect to it, the fundamental problem of determining why a lubricant reduces friction is considerably more involved. Various theories of the cause of friction have been proposed, based on interlocking surface irregularities and the molecular forces existing at the surfaces of bodies in intimate contact. None of these theories, however, explain all the observed facts. Considerable evidence indicates that properties such as hardness, melting point, elasticity and crystal structure can be correlated to a certain extent with the amount of friction.

Solids, gases and liquids can serve as lubricants but the latter are most common. The main properties that characterize a lubricant are viscosity and oiliness. Viscosity is the resistance to an impressed force offered by all liquids. Information on what types of liquids have the requisite viscosities and why is more or less incomplete. The larger the lubricant molecule, the greater the viscosity. Another factor involved in viscosity is the shape of the molecule. The more complex or rougher the contours of the molecule, the greater will be the change in viscosity with temperature. The viscosity index serves a useful purpose in educating people to think in terms of viscosity-temperature coefficients as related to lubricants, but it is based on arbitrary standards and must eventually be superseded by an index related in some way to more fundamental quantities. Some efforts along this line are already under way. Variations in external pressure introduce variations in viscosity which are fairly important in lubrication studies, but the determination of viscosity-pressure relationships of lubricants is rather difficult. The practical value of information on the correlation of chemical structure and molecular weight with viscosity characteristics lies in the ultimate possibility of being able to tailor molecules to a desired specification.

The second basic property of lubricants is oiliness—that property which allows a reduction in friction under conditions such that viscosity plays no part. Viscous effects are closely connected with oiliness but they cannot account for it completely. Most of the available evidence on oiliness indicates the existence of a (Cont. on page 810)

# "with GULF L. S. CUTTING BASE

we doubled tap life,  
reduced breakage, and  
improved thread finish"

says this Lubrication Supervisor



"WE make careful performance studies to insure that the cutting oil used for each particular job is the best we can select for that job," says this Lubrication Supervisor. "This policy has paid us big dividends in greater machining efficiency. When we switched to Gulf L.S. Cutting Base for tapping magnet yokes, for example, we increased tap life 100 per cent, reduced tap breakage, and improved thread finish."

The Lubrication Supervisor consults with a Gulf Lubrication Engineer (left) on results with Gulf L. S. Cutting Base A in tapping cold rolled iron magnet yokes for business machines.

Every Gulf Cutting Oil has specific properties which insure better performance on certain types of jobs! Call in a Gulf Lubrication Engineer today and let him show you how they can help you improve your machining practice. Write, wire, or phone your nearest Gulf office.

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**Brake Shoe**

BRAKE SHOE AND  
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## WHAT IS A LUBRICANT?

(Starts on p. 804) strongly held film which protects the surfaces of the contacting parts. The atoms in some metallic surfaces seem to be able to attract a large variety of these films composed of polar molecules. Variation in the strength and precise type of these forces, which range from chemical combination to very slight adhesion, can account for a considerable portion of the role which the lubricant itself plays in oiliness phenomena. The use of electron and X-ray diffraction techniques has proved the existence of ordered films, the presence of which has been correlated with frictional properties. There is no very complete or satisfactory explanation of oiliness and associated properties beyond the definite relation between these films and certain frictional characteristics. However, the mere possession of polarity is no criterion of oiliness, although it does indicate the possibility of film formation, and the existence of a film of this nature is no guarantee of lubricity.

A lubricant, therefore, can be defined more precisely as a material which effects a decrease in friction because of its viscosity and ability to form thin protective films of a specific type and composition. When lubricants can be thoroughly explained in terms of their constituent molecules, we will be well on our way to transforming the art of lubrication to a science. ☐

## AGE HARDENING Cu-Ni-Mn ALLOYS\*

A N INVESTIGATION was made of the casting, workhardening, annealing, heat treatment characteristics and physical properties of a series of high-purity copper alloys with up to 30% each of nickel and manganese. No serious difficulty was encountered, but alloys with more than 20% nickel and manganese were less readily workable than the higher copper alloys.

Workhardening curves of strip cold rolled 10 to 70% showed that the hardness (Continued on p. 812)

\*Abstracted from "The Physical Properties and Temper Hardening Characteristics of Copper-Nickel-Manganese Alloys", by Maurice Cook and W. O. Alexander. *Journal of the Institute of Metals*, V. 72, 1946, p. 381 to 401.

# CHROMAX® CUTS Annealing, Hardening & Carburizing HEAT-HOUR COSTS

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FOR THOSE CONCERNED WITH QUALITY HEATING OF METALS

### "Both Ends Against the Middle"

In heat treating high alloy castings at 2100° F., the Cooper Alloy Foundry Company, Hillside, N. J., saves fuel, floor-space and time through R-S furnace design here pictured.

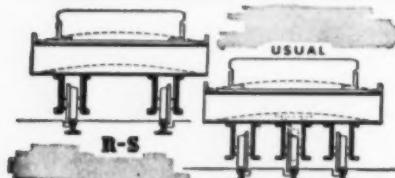
R-S provides doors at both ends of the furnace, and two car hearths. Thus, while one car is in the furnace and the charge is being heated, the other car is unloaded and reloaded, so that no time is lost between heats.



As a result (1) the fuel normally required to hold an empty furnace at heat while the charge is made ready is saved; (2) a smaller furnace produces more tonnage per day; and (3) furnace life is increased because less violent heat-and-cool cycle goes on in the furnace chamber. "Playing both ends against the middle," say R-S designers, "is desirable in the foundry."

A rotary hearth in Detroit  
Had holes in the wall like a quilt.  
Said a fellow named Schmaltz,  
At avoiding such faults  
R-S engineers are adroit.

R-S builds for the years, with the thought that every dollar saved in Maintenance is a direct addition to Profits. Considering that  $M = 3P$  (AISE figures) throughout the steel industry, you're on the right course when you specify R-S furnaces.



**Third wheels shirk the job . . .** Heat distorts a wide hearth (see dotted lines) so third wheels lift, and overload the others. The R-S solution is to design for ample "beef" so that two will do the job right.

**R-S Products Corp.**

## AGE HARDENING Cu-Ni-Mn ALLOYS

(From p. 810) increases gradually with the nickel and manganese contents for alloys containing equal amounts of these elements. Results on alloys with unequal proportions of nickel and manganese indicated that manganese increases the rate of workhardening more than an equivalent weight of nickel. Hardness tests on alloys quenched from 1650° F. and quenched and cold rolled 50% showed a progressive and gradual increase in hardness with increase in nickel and manganese. This would suggest that the alloys are uniform solid solutions when so treated.

The softening obtained by solution heat treatment increased as the temperature of treatment was raised to 1830° F. The optimum solution treatment was a water quench from 1470° F., since grain growth occurs at higher temperatures. The resulting diamond pyramid hardness was 83 to 120, depending upon analysis.

Hardness tests were made after holding for a maximum of 192 hr. at temperatures from 570 to 1290° F. Alloys containing more than 7% each of nickel and manganese were temper hardenable, the extent of hardening increasing with the nickel and manganese contents. For a given total nickel-plus-manganese content, the maximum hardening effect was obtained in alloys containing equal proportions of nickel and manganese. The departure from the 1:1 ratio could not exceed 10% for maximum hardening. The effect of deviations from this ratio was more marked with alloys containing more than 70% copper than in the lower copper alloys. The maximum temper hardening action was found at 795 to 840° F., irrespective of whether the alloys had been previously solution heat treated or solution heat treated and cold worked. The time required for maximum hardening decreased with increasing nickel and manganese. Thus, the alloy with 10% each of nickel and manganese required about 192 hr. to attain a hardness of about 300, whereas only 48 hr. was required to develop a hardness of 400 in the alloy with 20% each of nickel and manganese.

With such heat treatments several alloys attained diamond pyramid hardness values over 500; the maximum recorded was 586. On strip material, values of more than 134,400 psi. for (Cont. on p. 814)

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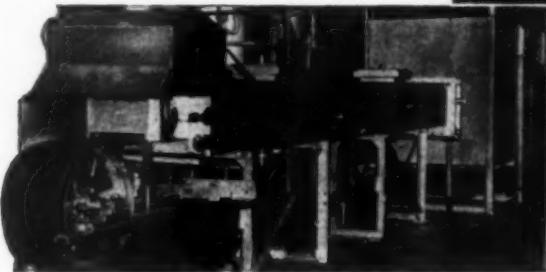
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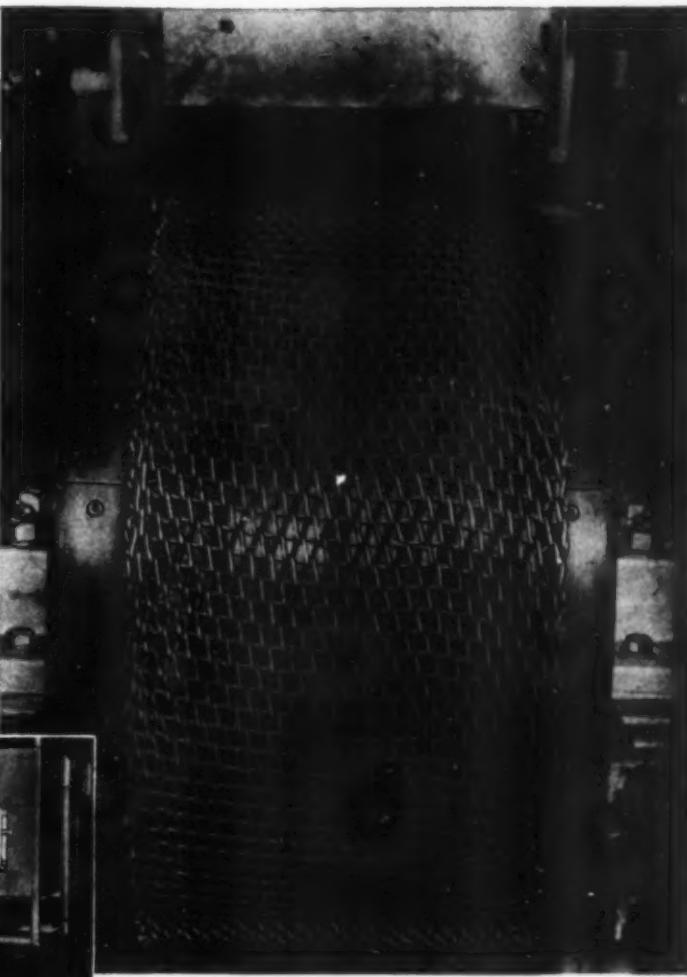
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"8,640 hrs. at temperatures  
from 1300 to 2040° F."  
...and this belt's  
still going strong

...and that's only  
part of the story



Copper brazing furnace of Beech Aircraft Corp., Wichita, Kansas, equipped with Inconel belt obtained through Electric Furnace Co., Salem, Ohio.



Here's proof of Inconel durability. After 8640 hours in temperatures from 1300 to 2040° F., this Inconel conveyor belt was found to be in excellent condition. Not a single link had to be replaced.

- When Beech Aircraft Corporation called for an Inconel\* brazing-furnace conveyor belt, they naturally expected long life. But, they got more. They got repair-free service. Their recent letter reads:

*"The Inconel woven wire belt on our copper brazing furnace was placed in service September 6, 1945 — 24 hours per day — for draw and copper brazing.*

*"It has been in continuous service since that date, except for down time of approximately 30 days during October 1946. At that time, repairs were made to the furnace, but not to the belt.*

*"This belt now has been in operation for a total of 8,640 hours at temperature range of 1300 to 2040°, the stand-by temperature being 1300°.*

*"We have made no replacements in the linkage to date."*

On scores of heat-treating jobs, Inconel is turning in

performances like the above. For, this metal was especially developed for high temperature work. It's strong, ductile, and of great thermal endurance.

It does not scale away through oxidation. Resists most all corrosive atmospheres encountered in heat-treating operations.

You can get Inconel in standard mill forms. It's readily fabricated into designs to fit your individual requirements. Send today for copy of the bulletin, "For Long Life at High Temperatures."

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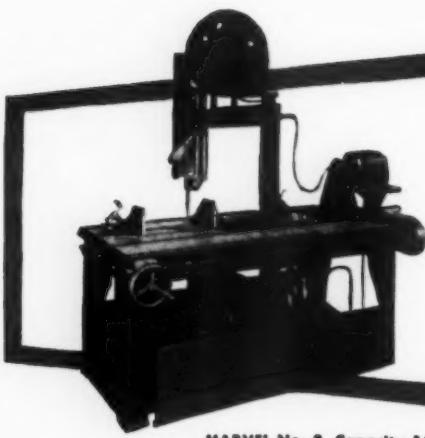
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**AGE HARDENING  
Cu-Ni-Mn ALLOYS**

(Starts on p. 810) 0.1% proof stress and 179,200 psi. for tensile strength were obtained. In some alloys tested, elongation of the quenched and cold worked strip was not decreased by the temper hardening. In others, it was even improved despite an increase of about 67,200 psi. in the tensile strength.

The properties obtained on rod were similar to those on strip, while tensile strengths up to 246,400 psi. were recorded on wire. The maximum values of proof stress and tensile strength did not always coincide with maximum hardness. A wide range can be obtained by varying composition and treatment.

**MAGNESIUM  
FOR CATHODIC  
PROTECTION\***

USE OF MAGNESIUM as a galvanic anode for cathodic protection is suggested by its strongly anodic solution potential and the theoretically small consumption per amp-hr. of current supplied. Other requirements of sacrificial anodes that must be satisfied for maximum effectiveness concern a uniform corrosion pattern, probability of segregation losses, and polarization characteristics as related to time, anode environment and rate of anode consumption. Attempts to control these variables have led to the use of controlled anode environments or chemical backfills which generally improve anode performance. For many applications, installation costs equal and may exceed anode metal costs, rendering anode efficiencies and current costs relatively less important. To such installations, the magnesium anode with its high potential and great throwing power promises adequate protection with fewer anodes and a corresponding cheapening of installation.

Experimental field work was started some six years ago with pure commercial magnesium ("cell" magnesium with 0.01 to 0.05% iron). Current flows on the whole were adequate but the anode life was short, efficiency poor and behavior erratic. (Continued on page 818)

\* Abstracted from "Magnesium Anodes for the Cathodic Protection of Underground Structures", by H. A. Robinson, *Corrosion*, V. 2, October 1946, p. 199 to 218.

# *the way for the "Big Blow"*

A typhoon is just a puff compared with the wind that whips through this test tube for model planes at Cornell Aeronautical Laboratory, Buffalo, N. Y. The "big blow" is created by two 22-foot diameter fans that can generate a wind of over 700 miles per hour.

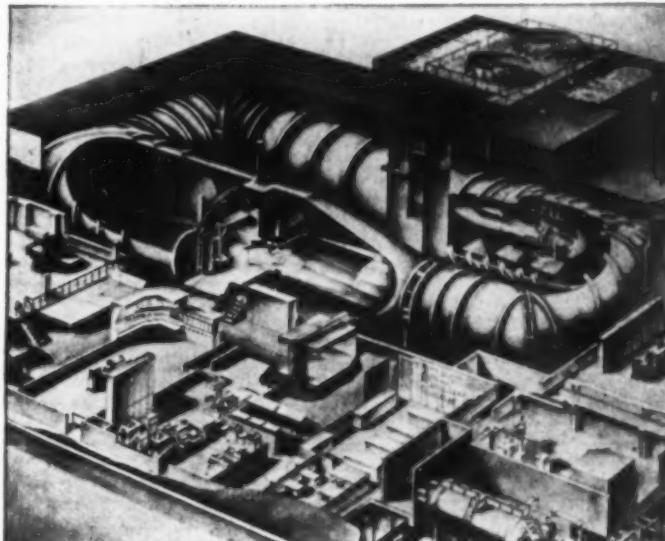
The inside walls must be smooth, scale free, since this gargantuan blast would shear off tiny little specks and drive them through a valuable test model plane with devastating force. To prevent this, every little bit of scale was removed from the thousands of square feet of metal surface before painting by Linde's flame-priming process.

Flame-priming is simple to do, requires little equipment, and costs little. A brush of oxy-acetylene flames pops off scale and drives out moisture. Paint applied to the warm, dehydrated surface spreads easily, goes on smoothly, bonds tightly, and lasts longer.

Linde service engineers are always available to help with problems of treating, cutting, joining, and forming metals. Linde research is constantly at work on the development of new and better methods in the production and fabrication of metals.

*Two huge 22-foot diameter fans, fabricated by UNIONMELT welding, generate the wind for high-speed tests simulating high-altitude conditions.*

words "Heliarc," "Linde," "Oxweild," "Prest-O-Lite," "Prest-O-Lok," "Purox," "Union," and "Unionmelt" are trade-marks of Union Carbide and Carbon Corporation or its Units.



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*Unit of Union Carbide and Carbon Corporation*

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When you have a COOLEY, there is no need to wait for large furnace time or use the power required to heat such a furnace. Always-ready COOLEY Furnaces give you convenient capacity for small work, together with highly accurate temperature control, simplicity of operation, unusual flexibility and an operating cost as low as 4¢ per hour. These efficient box furnaces are now available in 11 types and sizes to offer the correct model for your requirements (see table below).

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controlling pyrometer. This combination corrects the characteristic lag of chamber temperatures behind the pyrometer reading to as low as 300° F., and eliminates low temperature overshooting.

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MAX. TEMP.	1850° F.
AMPERES	14.8 at 230 v.
WATTS	3400
MODEL*	MH-3 VH-3 MK-3 VK-3
PRICE	146.00 166.00 186.00 206.00

CHAMBER	10" W 6" H 18" L
MAX. TEMP.	1850° F.
AMPERES	19.8 at 230 v.
WATTS	4500
MODEL*	MH-4 VH-4 MK-4 VK-4
PRICE	222.50 242.50 262.50 282.50

\* MH models complete with hinged door and hearth plate.  
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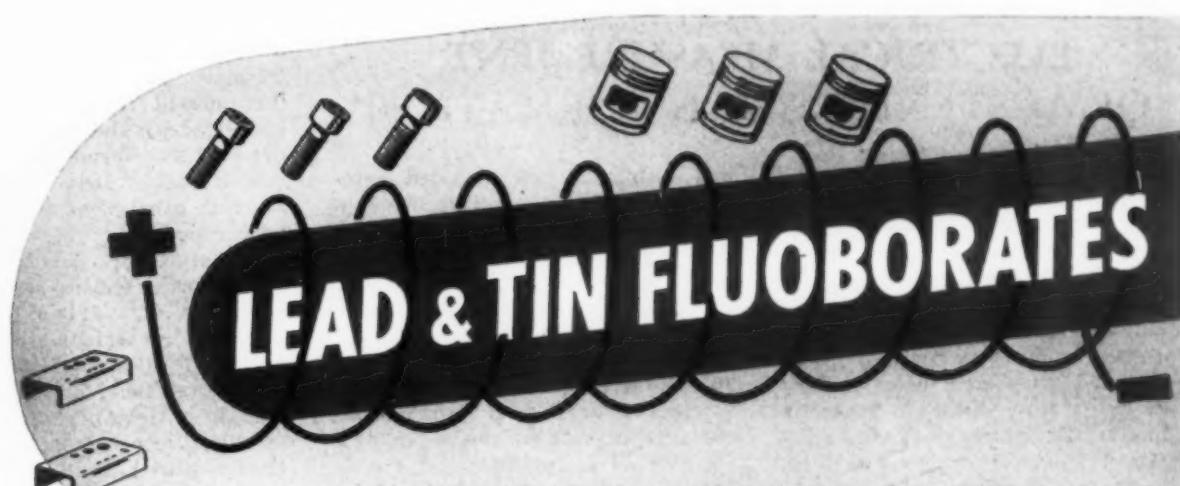
## Mg FOR CATHODIC PROTECTION

(Continued from page 814)

The three major variables that affect the corrosion pattern of the anode are anode current density, kind and concentration of electrolyte, and composition of the anode metal. Laboratory tests failed to reveal a chemical environment that was entirely satisfactory, but it was determined that the rate of local corrosion increases with the rise in current flow and the rate of increase in local corrosion approaches the rate of increase in useful corrosion. These data, together with the high rate of open circuit corrosion, served to explain why low efficiencies were observed with cell magnesium. Therefore, the cell magnesium anode is not likely to perform efficiently except at rather high current densities.

Over the low current density range normally used in field installations high-purity magnesium-aluminum and magnesium-aluminum-zinc alloys perform more efficiently. An alloy of high-purity magnesium with 6% aluminum and 3% zinc had the best over-all anode performance characteristics in the laboratory. The optimum distribution of corrosion attack at the anode was obtained with saturated solutions of calcium sulphate or magnesium sulphite as the test electrolyte.

Anode performance in the field has shown a progressive trend toward the laboratory level of performance as the improvements in anode composition and environment are incorporated into practice. Semifluid bentonite clay muds containing varying amounts of chemicals are being currently used for backfills. They have a number of advantages including intimate contact between the anode and adjacent earth, homogeneous anode environment, and good chemical stability. A number of bentonite-free chemical combinations are also being investigated. Anodes made of the 6% aluminum, 3% zinc alloy operated in one test at a maximum efficiency (average over-all efficiency 55%) in a bentonite backfill containing 0.5% chromium trioxide. For cell magnesium the best backfill was gypsum, with an average over-all efficiency of 32.5%. In general, the field data currently available do not cover a sufficient number of tests nor are they of sufficient duration to permit specific conclusions.



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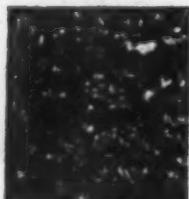


Fig. A. Lead Plating  
(100% Lead—0% Tin)  
150 Diameters

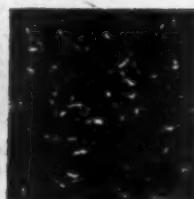


Fig. B. Lead-Tin Alloy  
Plating (91% Lead—  
9% Tin) 150 Diameters

When tin is plated out simultaneously with lead from General Chemical Lead and Tin Fluoborate solutions, the lead-tin alloy plate obtained consists of a smooth, even cover in contrast to the grainy surface of the lead plate alone.



Fig. C. X-ray pattern of Lead Plating.



Fig. D. X-ray pattern of Lead-Tin Alloy Plating  
(91% Lead—9% Tin)

Coarse grain spots in Fig. C coalesce in Fig. D to form more uniform lines, indicating finer grain structure. Only lead lines appear in both patterns since the tin atoms have entered the lead lattice to form an alloy in Fig. D.

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## ELECTRICAL MEASUREMENT OF AUSTENITE TRANSFORMATION\*

TWO GENERAL methods can be applied to the quantitative observation of the austenite-martensite transformation, namely, metallographic examination after heat treatment, and direct observation by simultaneously measuring temperature and some physical property connected with structure, such as thermal arrest, dilation, magnetic changes and the noise of structural change. These latter direct methods are limited to rather special conditions and are not suitable for obtaining complete data on the progress of transformation. A method utilizing electrical resistance measurements has therefore been developed that furnishes a complete record at all stages of cooling.

Small samples are cooled either in vacuum or air while temperature

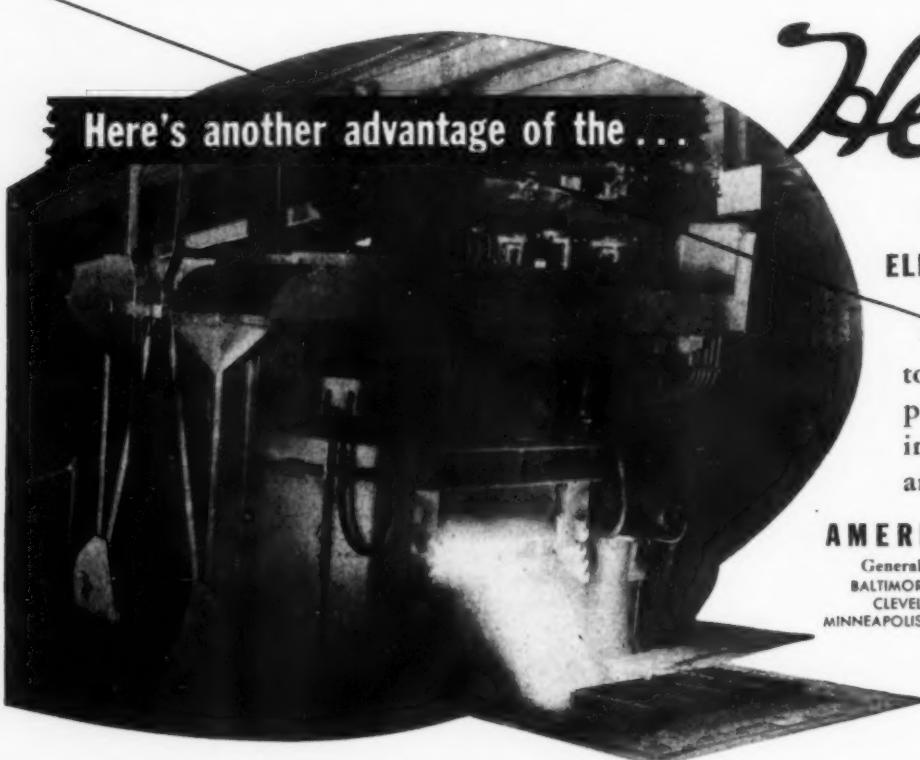
and resistance are recorded automatically. The temperature throughout the sample is uniform enough to permit a determination of resistance as a function of temperature.

The curves consist of two linear segments, one representing the resistance-temperature relation of 100% austenite and the other 100% martensite, while the connecting curve represents the resistance, as a function of temperature, of a mixture of the two constituents as their proportions continuously change with decreasing temperature. There is a sharp break in slope at the Ms point. If it is assumed that the linear austenite resistance curve can be extrapolated below the Ms point to show the resistance of untransformed austenite, then the position of the connecting curve can be used to indicate the proportions of the constituents present at any time and temperature. The resistance of the mixture depends on both the amount and distribution of the martensite plates. It is considered a sufficiently close approximation to assume that

the martensite forms in thin parallel plates at 45° to the direction of the current flow, extending completely across the sample. Thus the per cent transformation at any stage can be determined. The heat of reaction can be calculated from the measurement of the slope of the temperature-time galvanometer record. Local stresses set up by the formation of martensite seem to introduce no serious error.

Investigations on four steels show that the Ms point and the amount of transformation at a given temperature are independent of the time required for the steel to cool to that temperature (if no diffusion reactions occur) and of the rate of cooling through the transition region. This holds for rates of 1.8 to 180° F. (1 to 100° C.) per sec. above the Ms point and for times from 10 to 75 sec. to cool from the Ms point to the point of 90% transformation. If cooling is interrupted before transformation is complete, the formation of martensite ceases and resumes only when the temperature is reduced below the point of interruption. Agreement between the experimental Ms data and the values calculated from composition confirms that the (Cont. on p. 822)

\*Abstracted from "Electrical Observations of the Austenite-Martensite Transformation in Steel", by Andrew W. McReynolds, *Journal of Applied Physics*, V. 17, October 1946, p. 823 to 833.



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## AUSTENITE TRANSFORMATION

(From p. 820) Ms point is determined almost entirely by chemical composition. Calculations give heats of transformation of 19.8 cal. per g. for a steel containing 0.41% carbon, 0.26% manganese, 3.85% nickel, 1.85% chromium; and 24.5 for a steel with 0.09% carbon, 4.53% manganese, 0.93% molybdenum.

The electrical resistance method is applicable to almost any type of steel, including very low carbon, and steels that must be quenched very rapidly. Other advantages over metallographic methods are that the data obtained are precisely measurable, that measurements can be made during normal cooling and that a complete record of per cent transformation versus temperature can be determined from a single specimen.

low-temperature stress relief is merely a modification of mechanical relief wherein the phenomenon of expansion is used to apply a load to the highly stressed weld. The plate is differentially expanded on both sides of the weld in relation to the weld by running oxy-acetylene blowpipes parallel to and on each side of the weld. Water or air-water sprays cool the plate approximately 6 in. behind the heating flame to cause it to contract behind the heated area. A temperature of 350 to 400° F. is sufficient to relieve the weld stresses without overheating or upsetting the heated area. Stress measurements with electrical resistance strain gages of manual and Unionmelt butt joints showed that the high longitudinal residual stresses averaging about 43,000 psi. in the weld as welded were reduced to negligible values by the low-temperature stress-relieving treatment. The stresses transverse to the weld remained very low.

The effect of certain variables in the process was also studied. A 6 or 8-in. heating flame gives the best results on  $\frac{3}{8}$  or 1-in. plate but 3-in. wide heads are satisfactory for  $\frac{1}{4}$  and  $\frac{5}{8}$ -in. plate. The optimum condition is obtained with the

center line of the heated area 5 in. from the center line of the weld. A maximum heating temperature of 300° F. reduces the residual stresses by only about half while the residual stresses in the weld are reversed with heating to 400° F. An optimum maximum temperature of 350° F. was found for all plate thicknesses from  $\frac{1}{4}$  to 1 $\frac{1}{4}$  in. The cooling should not be too close behind the flame although the jet of water impinging on the weld may be omitted without increasing the residual stresses by more than a few thousand psi. Other factors are of relatively little influence.

In the stress relieving of intersecting butt welds it was found to be unimportant which weld is stress relieved first. At and near the intersection, marked stress reduction was effected even though only one weld was stress relieved. Even the high longitudinal stresses in the untreated welds were reduced 15,000 to 20,000 psi.

Low-temperature stress relieving has been effectively applied to the critical welds of ocean-going vessels both during construction and in dry dock after service. The speed of travel of the torches should be checked frequently. It is

(Continued on page 824)

## WELD STRESS RELIEF\*

WELDING induces locked-up stresses in all structures. These stresses may be divided into two general classes—reaction stresses and residual stresses. Reaction stresses are caused by shrinkage against the reaction of the surrounding structure and are inversely proportional to the distance between points of restraint. They are generally not large and can be minimized by proper welding procedure and sequence. Residual stresses in or immediately adjacent to the welded joints almost invariably approximate the yield strength of the weld metal in the longitudinal direction and are generally between 40,000 and 50,000 psi. The stresses transverse to the weld are somewhat variable and usually relatively small and unimportant. Since the restraint is inherent in the plates themselves, welding sequence is ineffective in decreasing residual stresses.

A low-temperature stress-relieving treatment has been developed which offers an effective and practical method of eliminating these residual stresses entirely or reducing them to negligible values without distortion or deformation. The

\*Abstracted from "Controlled Low-Temperature Stress Relieving", by T. W. Greene and A. A. Holzbaun. *Welding Journal*, March 1946, p. 171s to 185s.

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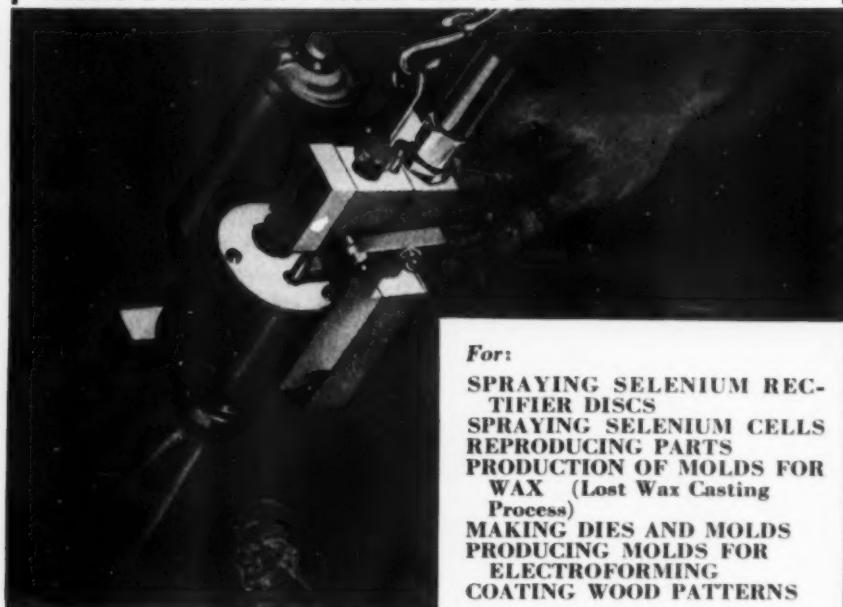


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## WELD STRESS RELIEF

(Continued from page 822)  
also recommended that the width and temperature of the heat bands be checked regularly with temperature-indicating crayons.

Extensive tests including fatigue, ductility and tensile investigations, impact tests from room temperature to -40° F., and metallographic examinations have shown that there are no detrimental physical or metallurgical changes if temperature does not exceed 350 to 400° F.

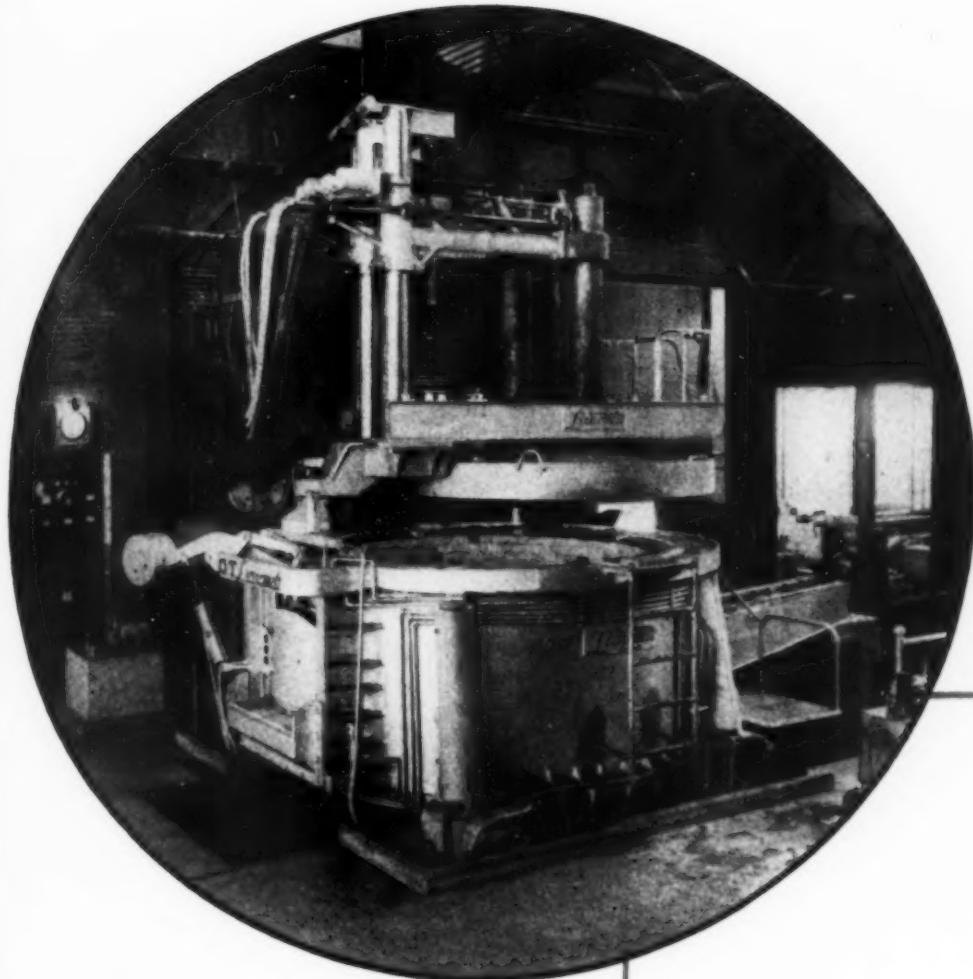
## SULPHIDES IN CAST IRON\*

FOR THE FULLER development of the potentialities of cast iron, sulphur should be regarded as a useful alloying element, whose effect depends almost entirely upon the manner in which it is present. In most commercial cast irons, with sufficient manganese to balance normal sulphur contents, manganese sulphide is the only sulphide to be seen (unless chromium content is high). Therefore, to investigate the possible occurrence of sulphides of other alloying elements, it is necessary to work with a low manganese content (about 0.2%) and high sulphur (0.16 to 0.70%) so that free iron sulphide as well as manganese sulphide will be present.

Nickel up to about 20% does not affect the form the sulphur takes, but it does neutralize the carbide-stabilizing effect of iron sulphide. Nickel may give rise to abnormal, mesh-like graphite believed to result from solidification of the iron in the white condition, followed by graphitization after solidification. A possible cause is the effect of temperature on the reaction between manganese and iron sulphide, since iron sulphide has a marked carbide-stabilizing effect while manganese sulphide is neutral. Thus, at certain critical compositions, it is conceivable that sufficient iron sulphide may be present during solidification to cause carbide stabilization but, at a lower temperature, when more manganese and less iron sulphide are present, graphitization will occur.

(Continued on page 826)

\*Abstracted from "The Neutralization of Sulphur in Cast Iron by Various Alloying Elements", by H. Morrogh. Advance Copy, Iron and Steel Institute, July 1946.



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covered in this report:  
Machined parts from rough forgings

Personnel interviewed:  
Machine Shop Supt. and General Foreman

Stuart Oil Products used in this plant:  
ThredKut 61, Solvol

Specific operations covered by this report:  
Drilling and boring forged "5060" steel pump liners

Performance details:  
"Problem was presented here in boring 7½" dia. holes through 11" dia. x 30½" solid forged pump liners running about 170 Br. Liners are run on two heavy duty lathes, one starting with a 1" dia. drill followed with a boring bar; the other a heavy boring bar used for removing entire 7½" of stock.  
"Solvol was performing well on 4615 steel, but when 5060 steel was substituted, they could barely get 1 to 1½ liners per day, from one lathe. Switching to ThredKut, tool life improved, but still only got one liner per tool  
"Then they called us in on the trouble. Our inspection of tools indicated dilution was in order. A 6-1 blend of ThredKut and Pffe. was decided upon...and it licked the job...they now turn out 3½ liners per day per lathe, meeting production schedules...and are very appreciative of our help in solving this problem."

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## SULPHIDES IN CAST IRON

(Continued from page 824)

Molybdenum up to 1.9% has no effect on the form of the sulphur but at 2.0% molybdenum a group of new phases is observed. One is thought to be "molybdenum carbide" and another iron sulphide combined with molybdenum.

Complex aggregates of copper sulphide, iron sulphide and manganese sulphide are found in the series with up to 5.9% copper. In the absence of manganese, a double sulphide or a solid solution of copper sulphide and iron sulphide may form; occurrence of a eutectic of this phase and copper sulphide is also possible. When manganese is present, the sulphides of manganese and copper may form a continuous series of solid solutions. Unless manganese is very low and sulphur and copper very high, no massive copper sulphide will be formed. The graphitizing influence of copper is weaker than that of nickel. As in the nickel-irons, abnormal graphite is found in the copper alloys.

Complex sulphides are found in all irons with 1 to 30% chromium. Chromium sulphide may occur associated with iron sulphide in striations or with manganese sulphide in a eutectiform pattern of spots. The gray chromium sulphide phase may be a combination with iron sulphide or manganese sulphide or both in solid solution. With about 30% chromium, the chromium sulphide replaces iron sulphide completely.

With aluminum up to 1.1%, only manganese sulphide with no iron sulphide is found. Irons with 2.2 to 7.8% aluminum show translucent, dark green particles which are probably aluminum sulphide ( $Al_2S_3$ ), perhaps containing some manganese sulphide in solution.

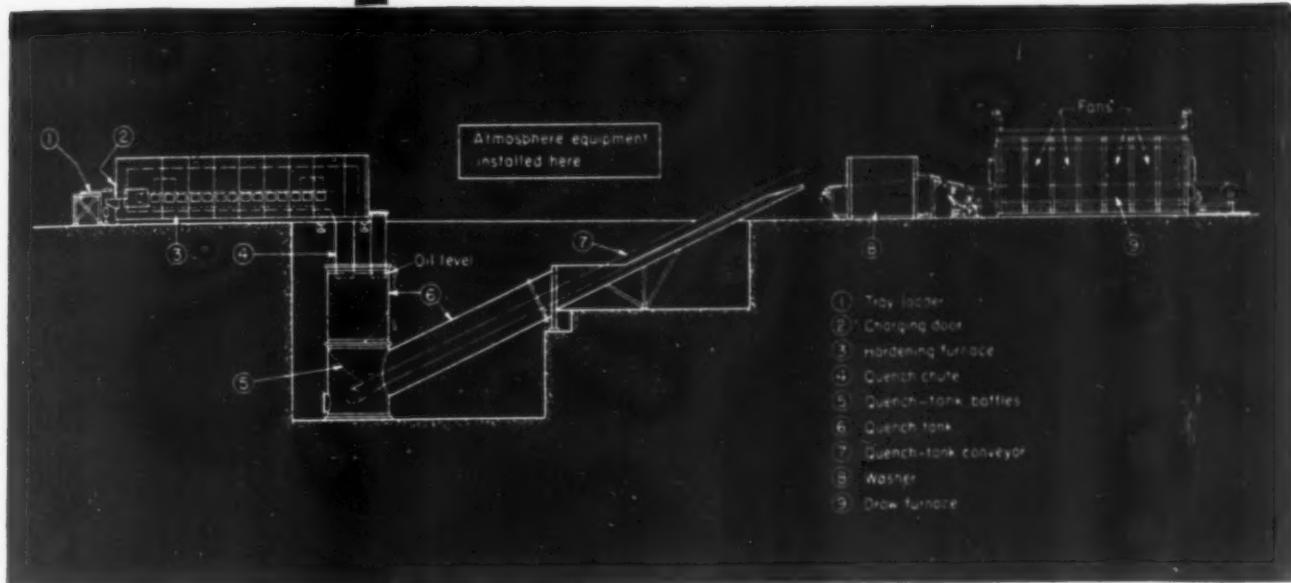
Pouring temperature appears to have no influence on the form. ♦

## INERT-ARC WELDING\*

THE INERT-ARC welding process developed by General Electric Co. resembles the more familiar atomic-hydrogen arc welding in its use of shielding gases and in its application mainly to thin metals. Inert-arc welding (Cont. on page 828)

\*Abstracted from "Some Notes on Inert-Arc Welding", by R. F. Wyer. Welding Ages, July 1946, p. 10 to 11.

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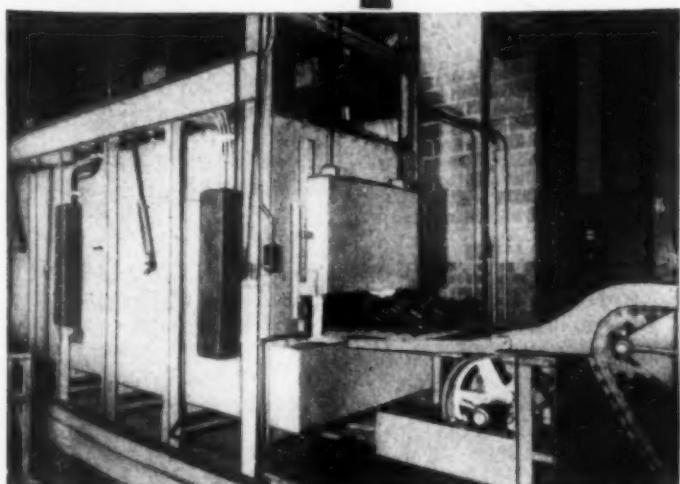
From the washer, parts are loaded directly into the charging end of the mesh-belt-conveyor drawing furnace. This complete, conveyorized equipment produces uniformly heat-treated parts much more rapidly, and at lower over-all cost.

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## INERT-ARC WELDING

(From p. 826) employs a single electrode, usually tungsten, in a holder which projects a smooth, low-velocity stream of helium or argon gas around the electrode and arc. When required, filler metal is added by means of a filler rod as in gas welding.

Direct current arcs are preferable for all metals thus far welded except magnesium, aluminum and beryllium-copper. Direct current should be used with straight polarity where possible. Since the shielded arc has a marked rectifying property, the two ends of the d.c. arc show unequal heating. With straight polarity (electrode negative), this gives a desirable condition with the electrode cool and the work hot. Reverse polarity produces a very hot electrode. Magnesium, however, requires reverse polarity if d.c. is employed, since straight polarity will not produce a good weld. Here a.c. has the advantage of a cooler electrode.

Today the largest use of a.c. inert-arc welding is for aluminum fabrication. A limited number of successful installations have been made of equipment stabilized by use of unusually high recovery voltages but these are more suitable for laboratory than for production work. The use of low-voltage a.c. circuits with superimposed high-voltage, high-frequency stabilization has been proposed but their general adoption is not likely because of the probability of troublesome radio interference. At present, equipment is being developed to weld aluminum with a special circuit which does not require high-frequency, high-voltage pilot spark units for stabilization.

The use of inert-arc welding is particularly attractive for light gage stainless steel because of the narrow heating zone, reduced warpage, relatively low first cost of equipment, good appearance and quality of the welds. Both manual and machine welding with direct current are producing excellent results. Either helium or argon can be used for shielding, but argon has the advantage of better arc stability for low current welding on very thin stock.

While the inert arc was first used commercially for welding magnesium, the present interest centers largely around stainless steel, aluminum, copper, thin mild steel and special alloys such as beryllium-copper and fernico.



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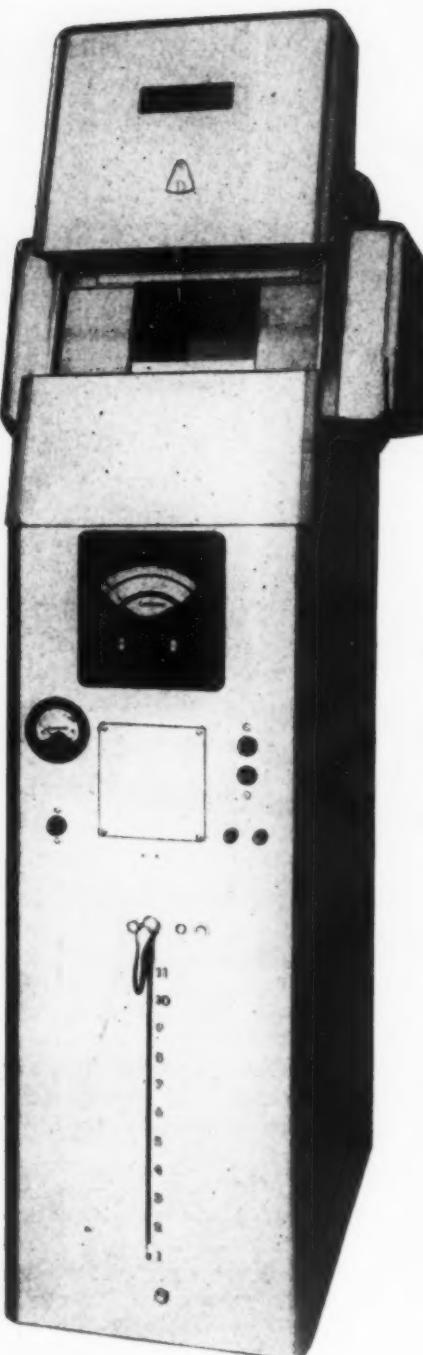
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## AGING OF ALUMINUM\*

USING a high-purity aluminum alloy with 4% copper, changes in microstructure and hardness on aging were studied. The alloy was aged both at room temperature and 265° F., and was cooled at various rates from the solution temperature. A selective "tarnish" etch of dry, very dilute hydrogen sulphide was used to identify the copper-rich particles.

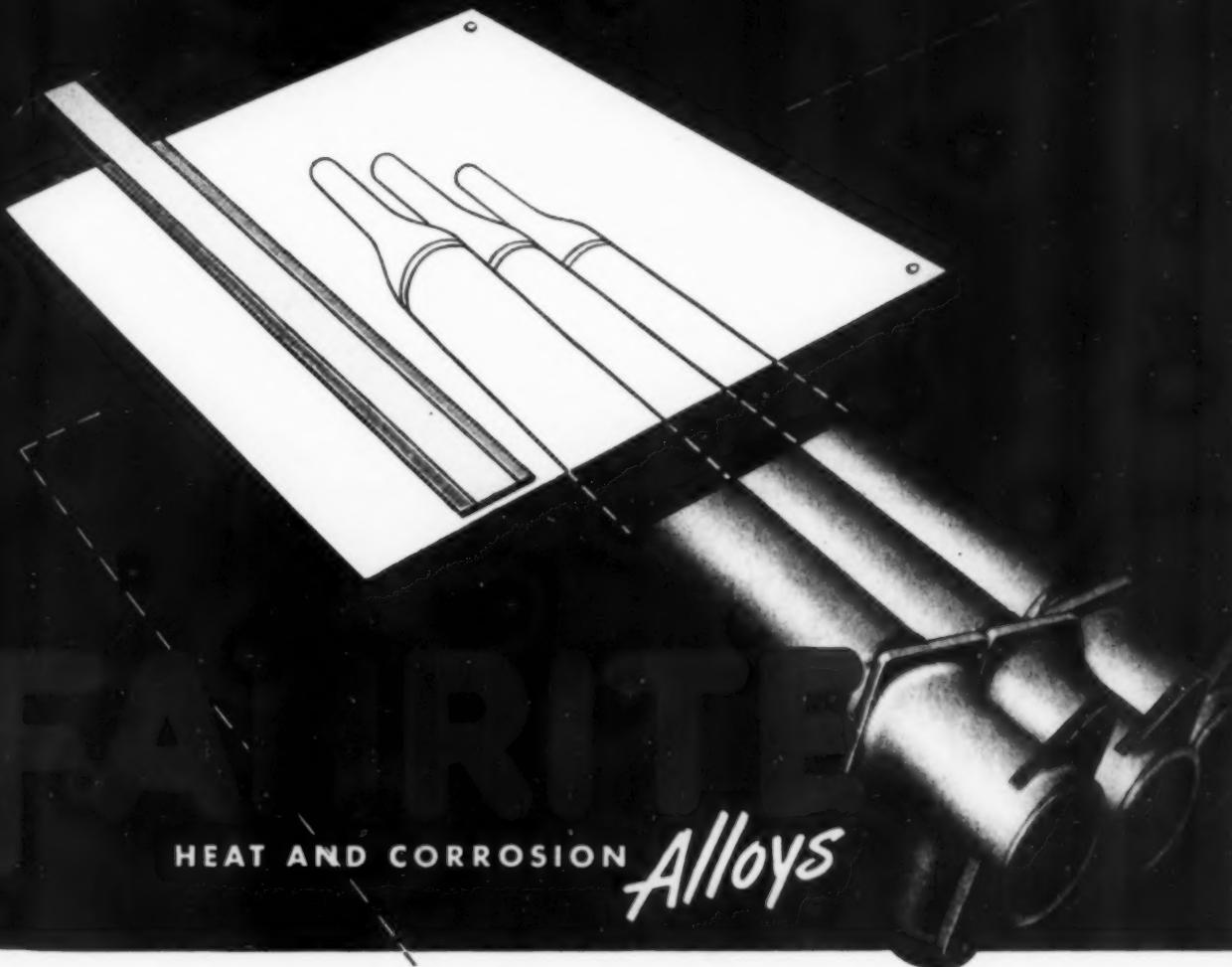
Results of the microscopic analysis may be summarized as follows: The first increase in hardness to a maximum is accompanied by no detectable change. The following flat on the time-hardness curves is accompanied by a submicroscopic change which is detected by the formation of minute etching pits in 25% nitric acid at 160° F. Since no change is observed in hydrogen sulphide, it is deduced that this is evidence of local electrochemical cells of submicroscopic copper-rich particles and adjacent areas of a new aluminum solid solution. After prolonged aging (the time depending on the temperature) the second hardness increase sets in and the microstructural changes become more marked. Crystallites of a new phase are observed, which are considered to be a new stable solid solution, while random, discrete copper-rich particles are revealed by hydrogen sulphide. As the hardness increases to a maximum, the number of crystallites and particles increases. After the maximum has been passed, the crystallites still persist. A new phase, alpha CuAl<sub>2</sub>, oriented with respect to the matrix, occurs along with marked softening.

Decreasing the quenching rate has a pronounced effect on aging at room temperature but at 265° F. the hardness curves differ only in the early stages. The difference in room temperature aging is a function of the number and size of particles formed during cooling from the solution treatment. The hardness increase depends on the amount of copper left in solid solution and thus is an inverse measure of the amount of particles formed during cooling. The initial differences in aging at 265° F. may be attributed to

(Continued on page 832)

\*Abstracted from "The Aging of a High-Purity Aluminum Alloy Containing 4% of Copper", by Marie L. V. Gayler. *Journal of the Institute of Metals*, V. 72, 1946, p. 243 to 263.

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## AGING OF ALUMINUM

(Continued from page 830)

the same cause, as well as to the re-solution of copper-rich particles and the formation of some new aggregates.

The evidence proves that age hardening of this alloy is due to the precipitation of copper or copper-rich particles and to the simultaneous formation of crystallites of the aluminum solid solution stable at the temperature of aging, and not to the precipitation of either alpha or beta CuAl<sub>2</sub>. The first increase in hardness results from the segregation of copper atoms to form plates on (100) planes, which increase in number and size depending on the aging temperature. The flat is associated with the formation of copper-rich aggregates of a critical size, depending on the aging temperature; their precipitation relieves the strain hardening in the surrounding matrix. Submicroscopic particles of copper or copper-rich aggregates are thereby precipitated and submicroscopic crystallites of the new aluminum solid solution are formed.

The second hardness increase results from two simultaneous processes—the growth of the submicroscopic particles to visible size and the formation of fresh aggregates in strain-free areas by the further diffusion of copper atoms. When softening has definitely set in, particles of alpha CuAl<sub>2</sub> are to be observed but only in strain-free areas. The polymorphic transformation of alpha to beta CuAl<sub>2</sub> takes place gradually in the softened alloy with no increase in hardness. The precipitation of copper-rich aggregates is a discontinuous\* process, while the precipitation of alpha CuAl<sub>2</sub> in alloys aged at temperatures higher than room temperature is a continuous process. If the aging temperature is high, so that there is little if any increase in hardness, alpha CuAl<sub>2</sub> is formed almost immediately, since the relief of strain hardening caused by the precipitation of any copper-rich particles in the formation of crystallites of the new aluminum solid solution will be practically simultaneous with the formation of alpha CuAl<sub>2</sub> in the copper-rich areas.

\*Mehl and Jette say that "continuous" precipitation occurs irrespective of grain boundaries and at uniform rates; "discontinuous" starts in restricted regions (primarily contiguous to grain boundaries) and spreads in an advancing wave.

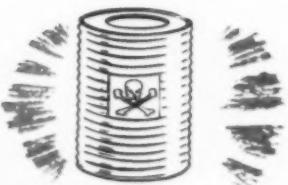
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## CONTROLLED EXPANSION ALLOYS\*

A RECENT and outstanding advancement is the development of age hardenable alloys of the Invar and Elinvar types which can be produced to have the desired expansion and thermoelastic characteristics with increased strength and hardness. The approximate composition of these alloys is as shown in the table.

The Ni-Span Lo alloys have low thermal expansion, Ni-Span Hi is a high thermal expansion alloy, and Ni-Span C is a constant modulus alloy.

The addition of titanium makes these alloys susceptible to age hardening. Certain compensating adjustments must be made for the effect of titanium to obtain the desired physical properties. Since carbon neutralizes four times its weight of titanium, the carbon is held to 0.06% maximum to assure good response to age hardening.

\*Abstracted from "Ni Span", by W. A. Mudge and A. M. Talbot. *Iron Age*, April 25, 1946, p. 66 to 70.

The titanium that does not form a carbide neutralizes more than twice its weight of nickel by the formation of an intermetallic compound. Therefore, the nickel content must be increased by 2.4% for each percent of noncarbide titanium.

Increasing titanium in the Ni-Span Lo alloys lowers the inflection temperature. Increasing tita-

Composition of the Alloys

NAME	Ni	Ti	Cr	Al	Fe
Ni-Span Lo 42	41.5%	2.4%	—	0.6%	bal
Ni-Span Lo 45	45.5	2.4	—	0.6	bal
Ni-Span Lo 52	52.0	2.4	—	0.6	bal
Ni-Span Hi	29.0	2.4	8.5%	0.6	bal
Ni-Span C	42.0	2.4	5.4	0.6	bal

nium in the Ni-Span C alloy moves the thermoelastic coefficient toward a negative value. Only minor changes in expansivity of the Ni-Span Hi alloy result from variations in the titanium content. Chromium increases slightly the rate of work hardening and decreases the response to age hardening. In the Ni-Span Lo alloys, nickel causes the

same changes in inflection temperatures and expansivity as in titanium-free alloys but at a higher nickel level. Increasing nickel content also results in a lower hardness for a given titanium content and in an increase in the temperature for maximum hardness in aging.

The alloys are softened to Brinell 125 to 150 by cooling rapidly from 1700 to 1850° F. Cold forming should be done before the final aging treatment. Hardening is accomplished by heating at 1100 to 1350° F. for 3 to 24 hr., depending

upon composition and the amount of previous cold work. The Ni-Span Lo alloys should be quenched from the aging treatment for minimum expansion characteristics, while air or furnace cooling is used for the other alloys. After 50% cold working and subsequent aging, the hardness of all alloys will be about Brinell 370 to 395.

The Ni-Span Lo alloys are used in applications requiring a low coefficient of thermal expansion and high strength, such as components of bimetal strips for thermostats, and instruments. Ni-Span Hi is used primarily for thermostatic controls, usually (Cont. on p. 836)

## For resisting HEAT, ACIDS or CORROSIVE GASES

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\*Recent experiments with the use of antimony in stainless steel indicate that chrome-nickel-antimony steels may be used to resist some of the acids shown in this list.

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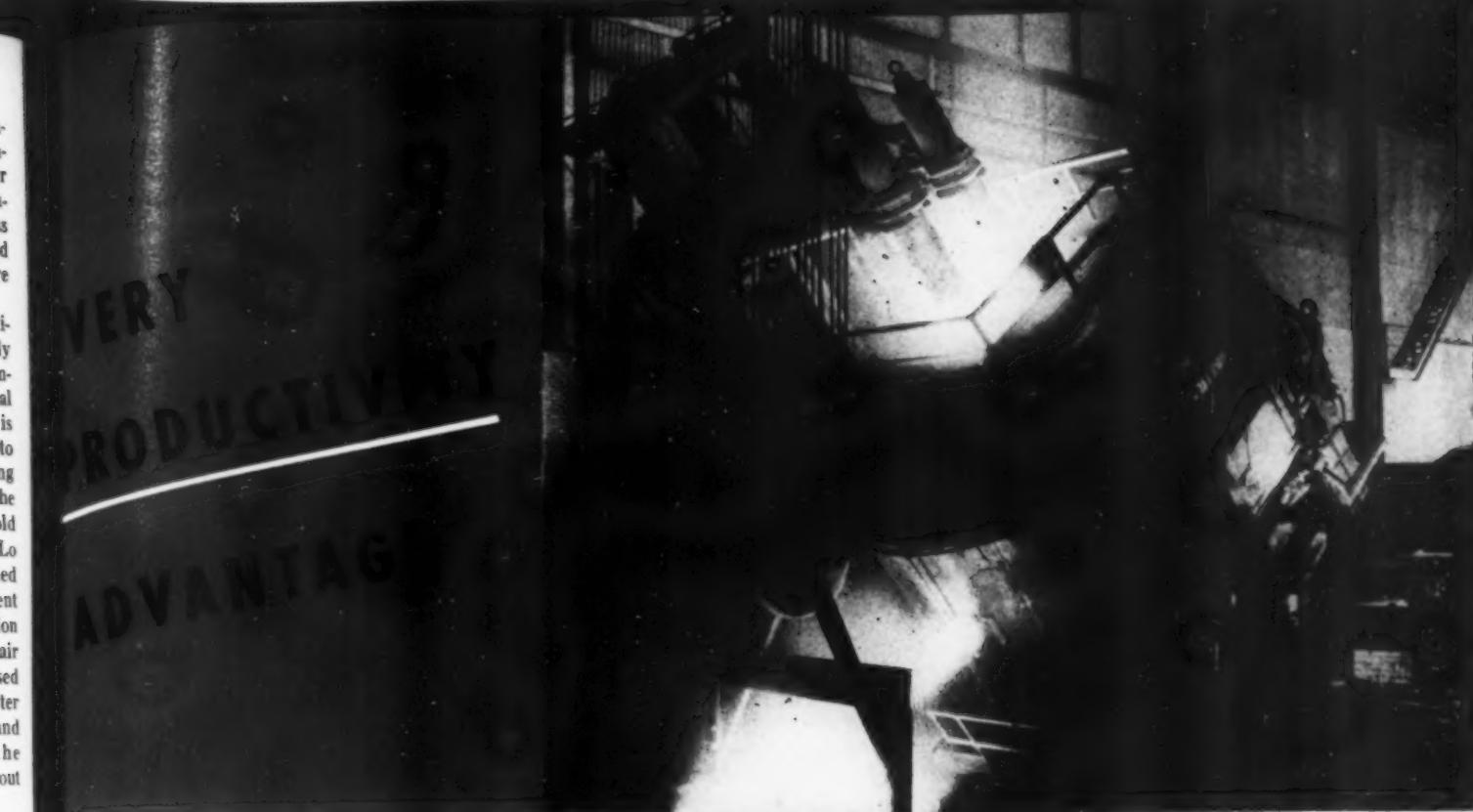
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## EXPANSION ALLOYS

(From p. 834) as one element of a bimetal. The advantages of the precipitation hardening alloys in this application are added strength, resistance to thermal and mechanical shock and improved properties at elevated temperatures. Ni-Span C is used primarily in instruments and machines for parts which must have no change or a controlled change in elastic properties with changes in temperature, such as springs for accurate scales, tuning forks and bourdon tubes. The titanium-containing alloys provide greater strength and a more adjustable thermoelastic coefficient. ♦

## TITANIUM\*

WHILE the metal titanium is the ninth most abundant element in the earth's crust, and of the metallic elements suitable for engi-

\*"Metallic Titanium and Its Alloys", by R. S. Dean and B. Silkes, Information Circular No. 7381, U. S. Bureau of Mines, Nov. 1946.

neering use is exceeded in quantity only by aluminum, iron and magnesium, the present industry largely has concerned itself so far with the production of white oxide pigment, and chloride for smoke screens, and only to a minor extent to weld-rod ingredients, alloys and cemented carbides. The metal itself is reduced from the oxide or chloride with difficulty, and the product is usually contaminated with much of the unused reagent, or if produced on a small scale, is contaminated during remelting or alloying.

A process developed by Kroll was modified by the Bureau of Mines to produce 100-lb. batches. Magnesium ingots are placed in an unlined iron crucible, tightly covered and evacuated to 0.005-mm. Hg while heated to 300° F. Helium at atmospheric pressure is then introduced, and the iron pot heated to 1400° F. Liquid  $TiCl_4$  is then slowly run into the pot, raising the temperature gradually at the end of the run to about 1650° F. The cooled receptacle is opened, the nugget milled into chips and the excess  $TiCl_4$ , Mg and  $MgCl_2$  leached out with cold HCl, and washed with dilute acid. The clean tita-

nium is then ground in a ball mill and iron removed down to 0.10% by a magnetic separator. Remaining amounts of hydrogen and magnesium are completely removed by sintering powder compacts at 1825° F. in a vacuum of  $1 \times 10^{-4}$  in. Hg. Compacting is done at 50 tons per sq.in. Sintered compacts are ductile when cold, capable of manufacture into sheet and bar. Annealed bars have 82,000 psi. tensile, 62,000 yield, 28% elongation in 2 in., hardness A-55. When cold worked the metal's corresponding properties are 126,000, 100,000, 4, A-65. Modulus of elasticity is 16,000,000 psi., melting point 3135° F. (1725° C.), density 4.5 g. per cc. (about half of steel). Corrosion resistance is similar to 18-8 stainless steel. Case hardening (to C-58) is possible by heating in helium containing a little free oxygen or nitrogen at 1750° F. for 24 hr.

Titanium, of course, has long been a valuable addition agent in the form of iron-base alloys to remove oxygen and nitrogen from molten irons and steels. This information circular contains several equilibrium diagrams of titanium binary systems, and a very complete bibliography. ♦

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